

**Section A1**  
**Alternative 1, Plasma Oxidation/Vitrification**

R1

**Advanced Thermal Processing Alternatives  
for Solid Waste Management**

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Of the seven emerging technologies discussed here, two (Energy Products of Idaho and Pedco Incorporated) use full combustion but in novel contexts. The other five processes (TPS Termiska AB, Proler International, Thermoselect Inc., Battelle, and ThermoChem Inc.) use gasification methods followed by fuel gas clean up. In niche market sectors and in the broader market, the five gasification technologies studied here are emerging as "commercially ready" alternatives.

The rate of penetration of the thermal processing market by new technologies will be paced by their environmental acceptability, their economic acceptability and their performance acceptability. From an environmental viewpoint, the seven technologies appear as a sound response to the regulatory challenges of the revised New Source Performance Standards (NSPS) and the Maximum Achievable Control Technology (MACT) rules<sup>2</sup>. Table 1 summarizes the process features and environmental characteristics of the seven processes.

Economics has always been a critical and probably pacing factor that affects the penetration of thermal processing technology in U.S. MSW practice. Table 2 summarizes preliminary economic data characterizing the seven processes. One must use caution in using these estimates since most of the processes are still evolving. Most of the processes have capital costs that are comparable to the \$121,000 per Mg/d (\$110,000 per t/d) typical of contemporary mass burn systems. The net operating cost, which is equivalent to the break-even tipping fee, for the gasification technologies are comparable to those for *owner-operated* mass burn facilities. The revenue stream from selling energy continues to be critical to overall economic acceptability.

The results are less clear concerning "performance." Most of the processes studied (excepting Thermoselect) require an RDF feed. Landfills are still required for RDF residues and/or ash. Historically, most RDF facilities have incurred substantial post-construction rework, capital investment, down-rating of capacity etc. Most of the seven systems have significant development tasks ahead of them. Unfortunately, the catalyst of vigorous U.S. market activity is lacking to push this development and to foster risk-taking. Further, many systems are quite complex. This presents some problems in gaining acceptance by client communities, by regulatory authorities and from the financial and engineering entities involved in concept selection and project accomplishment.

## APPROACH TO THE ANALYSIS

Initially, more than 45 firms were identified as possible candidates. A two-stage screening process selected seven firms to be evaluated in detail. Data received from the 45 were analyzed to produce the recommendation for the list of seven firms as limited by available study funds. The scope of the detailed evaluation effort for the seven selected technologies was broad. Data for the detailed evaluation were obtained from the developers based on a faxed request, a detailed questionnaire, and extensive technical discussions before and after site inspection visits.

The evaluation included exploration of *technical issues* affecting the basic process feasibility, reliability, workers' safety, operability, and maintainability. Very important was the remaining degree of scale-up from the present level of development to commercially useful equipment. Also, operating experience was seen as critical.

bubbling and circulating type fluid bed (Figure 2). The lower, bubbling bed section provides the extended residence time for the burnout of massive or very wet feedstocks. As the particles shrink, they enter the circulating bed zone where gasification is completed and the ash is swept from the furnace. Following the gasification bed, TPS inserts a second circulating bed "cracker" unit. In the second bed, a ground magnesium-calcium carbonate (dolomite) is injected to catalyze the conversion of high molecular weight tarry gasification byproducts into low molecular weight, non-condensable compounds. Also, the alkalinity of the dolomite reduces acid gas concentrations. The TPS system produces medium heat content fuel gas.

The technology offered by TPS is presently close to commercial availability. In 1992, a commercial, two-bed unit was installed in Grève-en-Chianti, Italy with a combined capability of 30 MW to gasify 100 percent pelletized RDF fuel or coarsely shredded wood or agricultural residues.

The manufacturing methods for the TPS-design gasifier systems, the long-term operability of their beds with acceptable management of bed solids, the projected emission control performance, the feeders, etc., have all been tested at Grève in MSW-based RDF service. Therefore, it is believed that the TPS system should be implementable with only moderate technological risk.

### **3. Proler International Corporation**

The Proler SynGas Process is a patented technology to reform hydrocarbon-containing wastes into a gaseous product. It is represented by a 1.8 Mg/h ( 2 t/h) demonstration plant in Houston, Texas. The process was originally developed to gasify automobile shredder waste (ASR) but limited test results show its suitability to process MSW. Proler feeds preshredded material into a rotating, kiln-like reactor (Figure 3). In the proposed commercial process, the reactor is fired with the hot exhaust gases from a "Vitrifier" auxiliary unit that uses part of the product gas, carbon char and oxygen to melt the mineral residue. The overall process produces a medium heat content fuel gas that, after cleanup, is suitable for power generation or other fuel uses. The residue is discharged as what is stated to be a "commercially useful byproduct".

Proler states that preliminary design work has been completed for a full-scale 865 Mg/d (960 t/d) commercial facility using MSW as feed stock and consisting of two process lines at 18 Mg/h (20 t/h) each. However, some technical issues require resolution before successful commercialization for MSW can be assured:

- The demonstration plant is now processing an RDF at a top size of 5.8 cm (2 in.). Proler expects the commercial plant to accept shredded material with a top size of 15.24 cm (6 in.) as a process change to achieve cost reduction in waste processing. This substitution may have adverse process impacts and has not yet been sufficiently tested to accept the change as acceptable.
- The demonstration plant has operated only on a limited basis with shredded MSW. An extended campaign of operation is essential to evaluate potential problems.
- The reliability and performance of the Vitrifier and the integration of this equipment with the existing gasifier have not yet been accomplished.

- Waste heat recovery to improve overall plant thermal efficiency to include finding uses for low grade heat.
- Continuity and reliability of operation needs to be confirmed. The demonstration plant has only been operated on a five day per week cycle. Continuous, seven-day per week, around the clock operation is yet to be shown.
- Scale-up. The current demonstration plant is reported to have a "nominal capacity of 4 Mg/h (4.4 t/h)" but, experience to date shows that the unit appears to operate at an actual throughput of only 3.8 Mg/h (4.2 t/h). The "Standard Design" two-line capacity is 10 Mg/h (11 t/h) or 240 Mg/d (264 t/d). Therefore, the scale-up factor based on actual operational experience is about 2.7:1. The success of the planned commercial size facility is yet to be proven.

## 5. Battelle

The Battelle High Throughput Gasification System (BHTGS) uses indirect heating in a twin circulating fluidized bed (CFB) gasifier and combustor (Figure 5). RDF is gasified in a CFB using steam as the fluidizing medium to generate a medium heating value gas 18.6 to 22.4 MJ/Nm<sup>3</sup> (500 to 600 Btu/sft<sup>3</sup>) without oxygen. Residual char is consumed in an associated CFB combustor. A circulating sand phase exchanges heat between the separate reactors.

Battelle's process development began in 1977. Detailed process development activities were begun in 1980 with the construction of Battelle's process research units (PRUs). Experimental data have been generated in gasifiers of 15 cm (6 in.) diameter and 25 cm (10 in.) diameter with a throughput of 0.22 and 9.1 Mg/d (0.24 and 10 t/d) dry RDF, respectively. Data from these showed that extremely high throughput, more than 19.5 Mg/h-m<sup>2</sup> (4,000 lb/hr-ft<sup>2</sup>) could be achieved.

Tests showed the technical feasibility of the gasification process and provided the basis for detailed process conceptual design and economic projections to be generated. Testing was conducted in 1989 in a 25 cm (10 in.) internal diameter gasifier with a height of 6.9 m (22.7 ft) and a 1.0 m (40-in.) internal diameter combustor with a height of 3.5 m (11.5 ft). The throughput was 0.65 Mg/d (0.72 t/d). The longest continuous operating run was approximately 100 hours at 9.1 Mg/d (10 t/d) dry RDF. A 200 kW gas turbine has been installed on the PRU and operated with recharges from wood for about 60 hours as an integrated gasifier-turbine system.

Battelle has licensed its BHTGS Process to Future Energy Resources Corporation (FERCO) of Atlanta, Georgia for the North American market. A commercial scale demonstration is underway at the Burlington Electric's McNeil Generating Station in Burlington, Vermont using wood chips.

The BHTG process is said to produce gaseous emissions from the reactor complying with the EPA's MACT standards and NSPS for municipal waste combustors (MWC)<sup>1</sup>. Wastewater from the process contains only trace quantities of organic materials. The outlet of a simple industrial treatment system at Battelle's test site showed wastewater to be within the EPA's drinking water standards.

Major unresolved development and demonstration needs include:

- Important process development issues relate to fuel preparation and reactor gas cleanup.

which to specify their optimum top size. Development of a generalized RDF flow sheet should not be problematic. One notes, however, that most RDF facilities have required extensive redesign and reconstruction effort to bring the RDF processing elements to an acceptable level of reliability and performance.

Major unresolved development and demonstration needs include:

- Pedco must select or develop a full system concept and associated detailed specifications starting with RDF receipt and processing and including electrical generation and residue handling.
- Continuity and reliability of operation of an RCBC system must be confirmed in RDF service. Problems associated with fouling and/or plugging of the ash handling chutes with wire and oversized non-combustible materials; fouling problems with boiler tubes; air emissions; and tube abrasion and corrosion problems must be assessed in continuous RDF service.
- Experience to date with the cluster of boiler tubes inserted into the RCBC device has been limited to low pressure, saturated steam. To maximize power production, higher pressures and superheated conditions are preferred. Higher skin temperatures on the tubes may affect erosion and corrosion sensitivity and should be evaluated before commitment to a full scale facility.

## **7. ThermoChem Incorporated**

The Manufacturing and Technology Conversion International, Inc. (MCTI) Steam Reforming Process is an indirectly heated fluidized bed reactor using steam as the fluidizing medium (Figure 7). Under license from MCTI, ThermoChem, Inc. (TC) have the exclusive rights to apply its Pulse-Enhanced™ heater and steam-reforming technology to a variety of applications.

Pulse Enhanced™ indirect heating technology combined with fluid-bed and steam-reforming provides a process for converting the organic material in an RDF to fuel gas while separating the inorganic without oxidation or melting. The key to the process is the array of Pulsed Enhanced™ heater tubes immersed in the fluidized bed. Gaseous fuel is burned in the tubes such as to create an oscillating pressure. The effect of the pulsing flow is to significantly enhance heat transfer between the combustion products and the tube wall. This greatly increases the efficiency of energy exchange between the fuel and the bed material. The organic waste fed to the fluid-bed steam reformer reacts with steam to produce a medium heat content fuel gas.

MCTI's development efforts began in 1984. Experimental data have been generated in different scale reactors from 9.1 to 2,722 kg/h (20 to 6,000 lb/h) using various biomass and waste feedstocks. A 13.6 Mg/d (15 t/d) demonstration unit was operated on rejects from a cardboard recycle paper mill in Ontario, California in 1991-1992. Later, this unit, moved to TC's test facility in Baltimore, processed coal, woodchips and straw.

Based on 6.8 kg/h (15 lb/h) pilot plant tests, the TC Process appears to comply with the EPA NSPS for MWC's. Tests suggest the residue meets EPA TCLP leachability criteria set for landfill disposal as a nonhazardous waste. Wastewater contains only trace amounts of organic materials.

The residues from the processes do not present problems in the Toxicity Characteristics Leaching Procedure (TCLP) leaching tests. The quantity of data in this area, however, is limited and experience in mass burn plants suggests that significant variation in TCLP results can be expected. Two of the processes (Thermoselect and Proler) include process steps where the residues are melted (vitrified). For these processes, the TCLP results are exceptionally low since the metals are bound in a glass structure and cannot be readily solubilized. Both firms believe that the vitrified residue granules may be marketable and, therefore, that their process will have a lower operating cost than is shown in Tables 2a,b. As yet, however, the value of the granules, if any, has not been established in the U.S. marketplace.

The overall conclusion that can be drawn is that competitive alternatives to conventional mass burn or refuse derived fuel (RDF) combustors exist. The alternatives may not offer exceptional economic advantages. Most of the processes studied present a much lower air emission profile than do conventional plants. This may merit investigation by communities or regional jurisdictions considering volume reduction technology where air emissions are of particular concern. One should note, however, that conventional mass burn technology can also meet the recently promulgated MACT and NSPS<sup>2</sup> emission requirements. The economic data in Table 2 is intended to provide perspective; not to be directly applicable to a specific situation. *To obtain fair, applicable economic data, cost issues should be addressed directly with the firms* (see Appendix A).

The preceding technical descriptions, many of the economic estimates and the prospective environmental performance would suggest that these new technologies define the future of WTE facilities. However, with the exception of EPI and, to a degree TPS, all of the processes have important development and/or demonstration steps between the present status and proven commercial availability. All except Thermoselect require processing of MSW to an RDF, possible but always problematical. Experience with Purox, Landgard, Torrax and many other processing technology developments in years past has shown that commercial and technical success does not come easily if at all. The unrelenting crucible of 24 hours a day, seven days a week operation in combination with the malevolent nature of refuse clearly presents a profound challenge to the process developer.

Also, most of the process developers suggest optimistic overall energy recovery levels. However, almost all lose energy in the RDF-making step. Some use a water quench to cool the synthesis gas, thus losing 400 to 600 Btu/lb MSW in sensible heat. Others achieve superior environmental characteristics at the price of greatly increased process complexity and higher capital and operating costs. Several firms are small and will suffer with the extended facility development schedules and under the draconian financing requirements of most U.S. system procurements.

Still, the adventure and excitement of technical innovation and the promise of successful commercial development spurs these firms forward. The professionalism, the high technical standards, and the business commitment in most of the seven development firms were impressive. Further, despite a weak U.S. market, most firms are aggressively seeking clients for that vital "first plant." I wish them well.

## REFERENCES

1. Niessen, W., Marks, C., and Sommerlad, R., "Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste," Contract YAR-5-15116-01 report to the National Renewable Energy Laboratory, July 1996.
2. Federal Register, *December 19, 1995* - 40 CFR Part 60.



Table 1 Environmental Comparison of Developing Technologies

Process Name	Thermal Treatment Technology	Air Pollution Control	Water Pollution Control	Residue Treatment or Disposal
EPI, Inc.	Bubbling Fluid Bed Combustor	Lime Spray Dryer Absorber, Fabric Filter, Selective Noncatalytic Reduction, Activated Carbon Injection	None: Dry System.	Landfill
TPS Termiska AB	Circulating Fluid Bed Gasifier with Dolomite Cracker	Scrubbing of Fuel Gas to Remove Particulate Matter, Condensable Organics, and Acid Gasses, NO <sub>x</sub> <sup>1</sup>	Cleanup of Scrubber Liquor. Not specified. <sup>2</sup>	Landfill
Proler International	Rotary Reactor Gasifier and Cyclonic Ash Vitrifier	Fabric Filter, Wet Scrubber, NO <sub>x</sub> <sup>1</sup>	Cleanup of Scrubber Liquor. Not specified. <sup>2</sup>	Proposed Sale as Vitrified Aggregate; Otherwise landfill.
Thermoselect, Inc.	Raw Waste Gasifier	Acidic and Alkaline Scrubber, H <sub>2</sub> S Removal, Activated Coke, NO <sub>x</sub> <sup>1</sup>	pH Adjustment, Metal Precipitation, Filtration, Distillation.	Proposed Sale as Vitrified Aggregate; Otherwise Landfill.
Battelle	Circulating Fluid Bed Gasifier and Combustor	Wet Scrubber, NO <sub>x</sub> <sup>1</sup>	Cleanup of Scrubber Liquor. Not Specified. <sup>2</sup>	Landfill
Pedco Incorporated	Rotary Cascading Bed Combustor	Lime Spray Dryer/Absorber, Fabric Filter, Selective Noncatalytic Reduction, Activated Carbon Injection.	None. Dry System.	Landfill
ThermoChem	Pulse-Heated Circulating Fluid Bed Gasifier		Cleanup of Scrubber Liquor. Not specified. <sup>2</sup>	Landfill

Notes:

1. NO<sub>x</sub> control may be required for the gas engine or turbine combustor.
2. Details of treatment were no specified by the developer.

Figure 1. Energy Products of Idaho Process Flowsheet

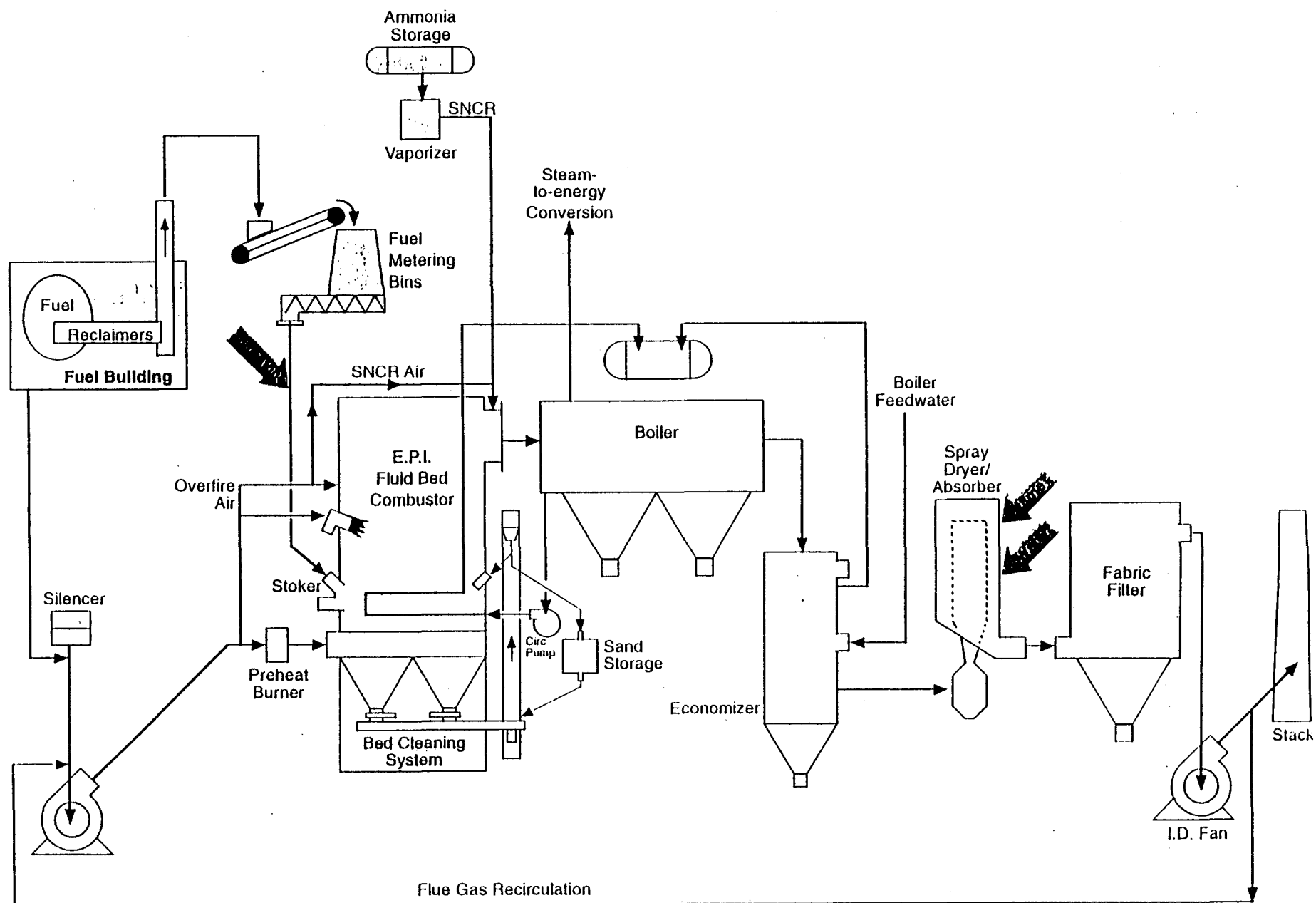
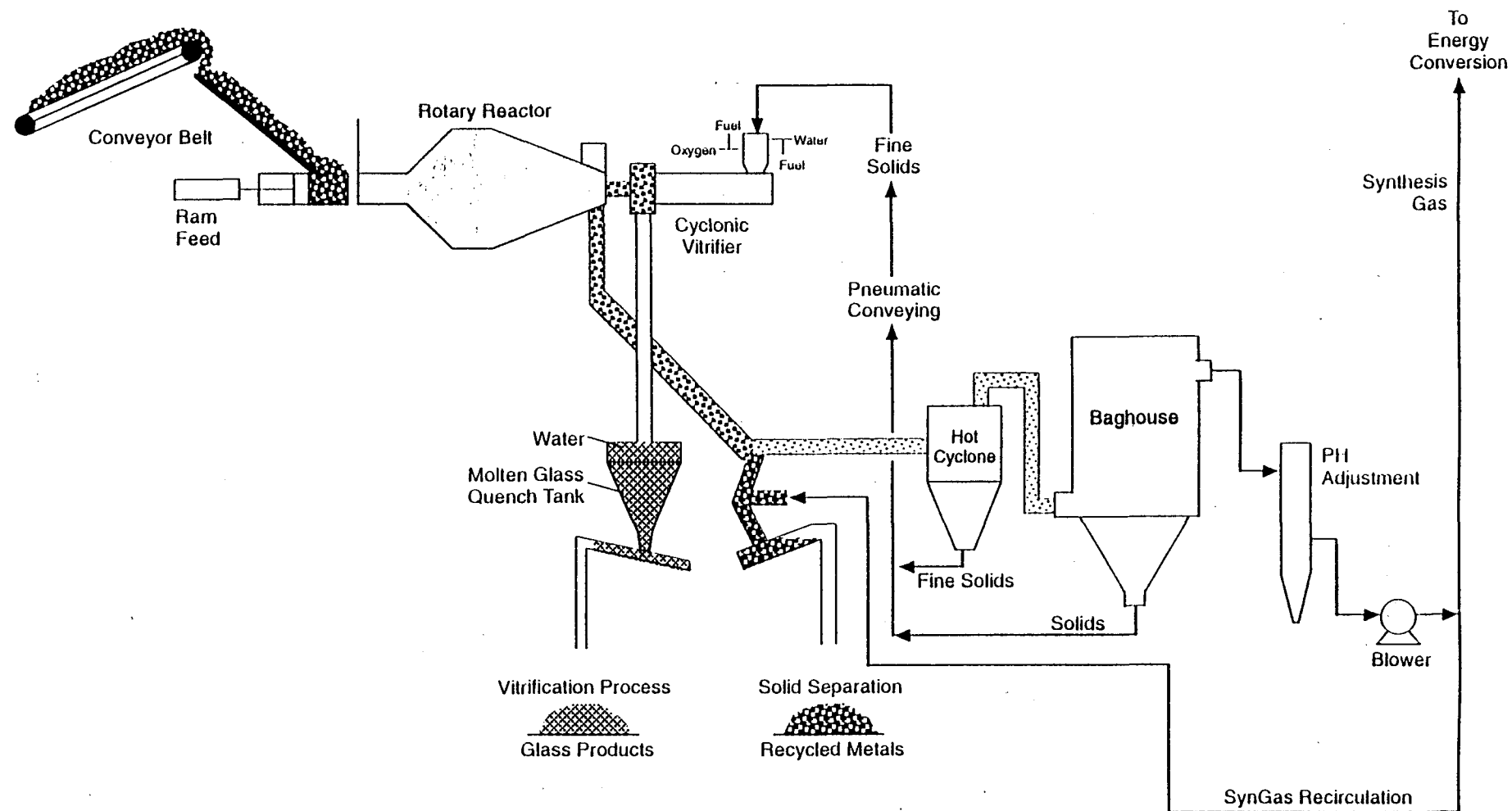
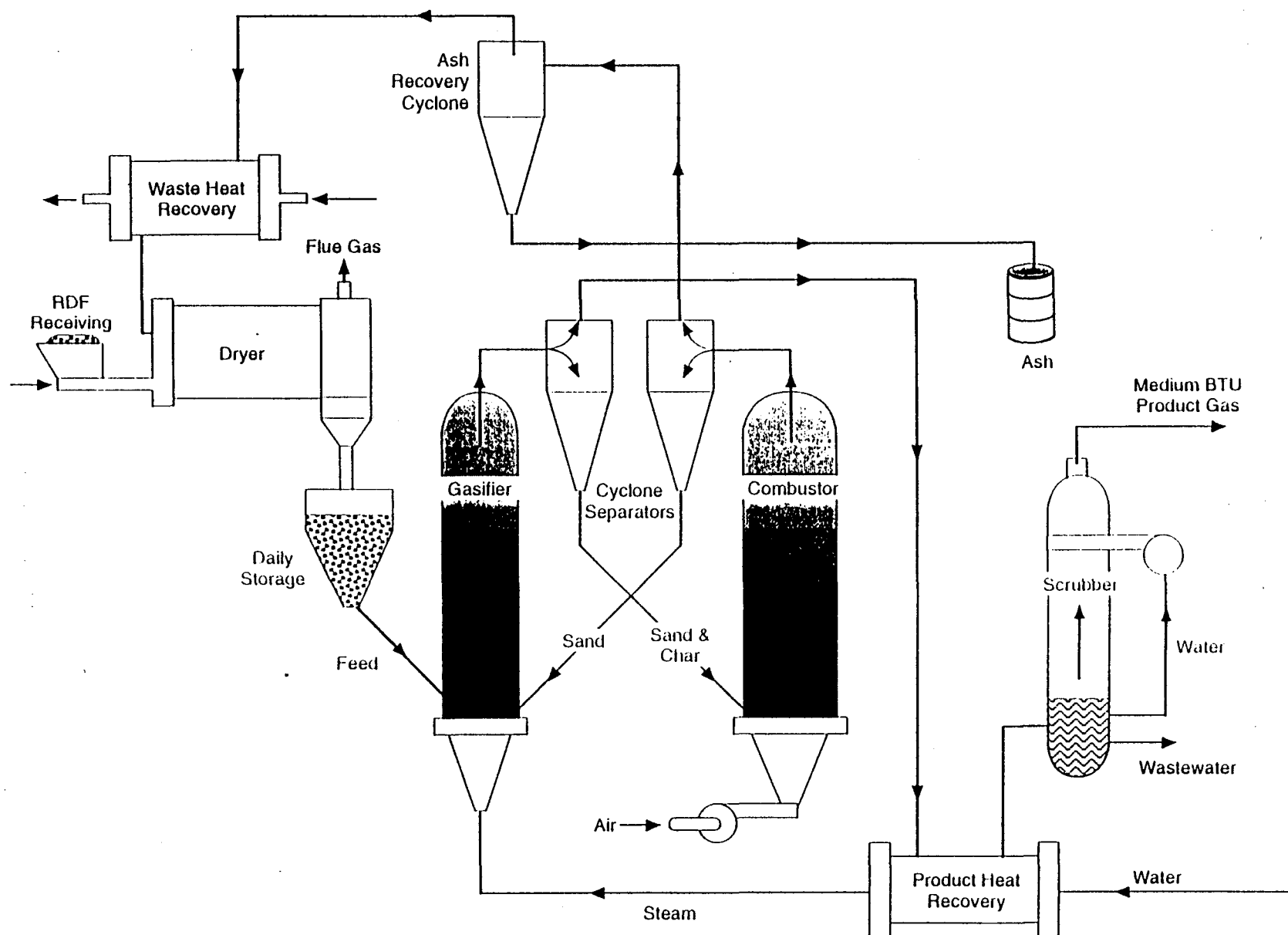
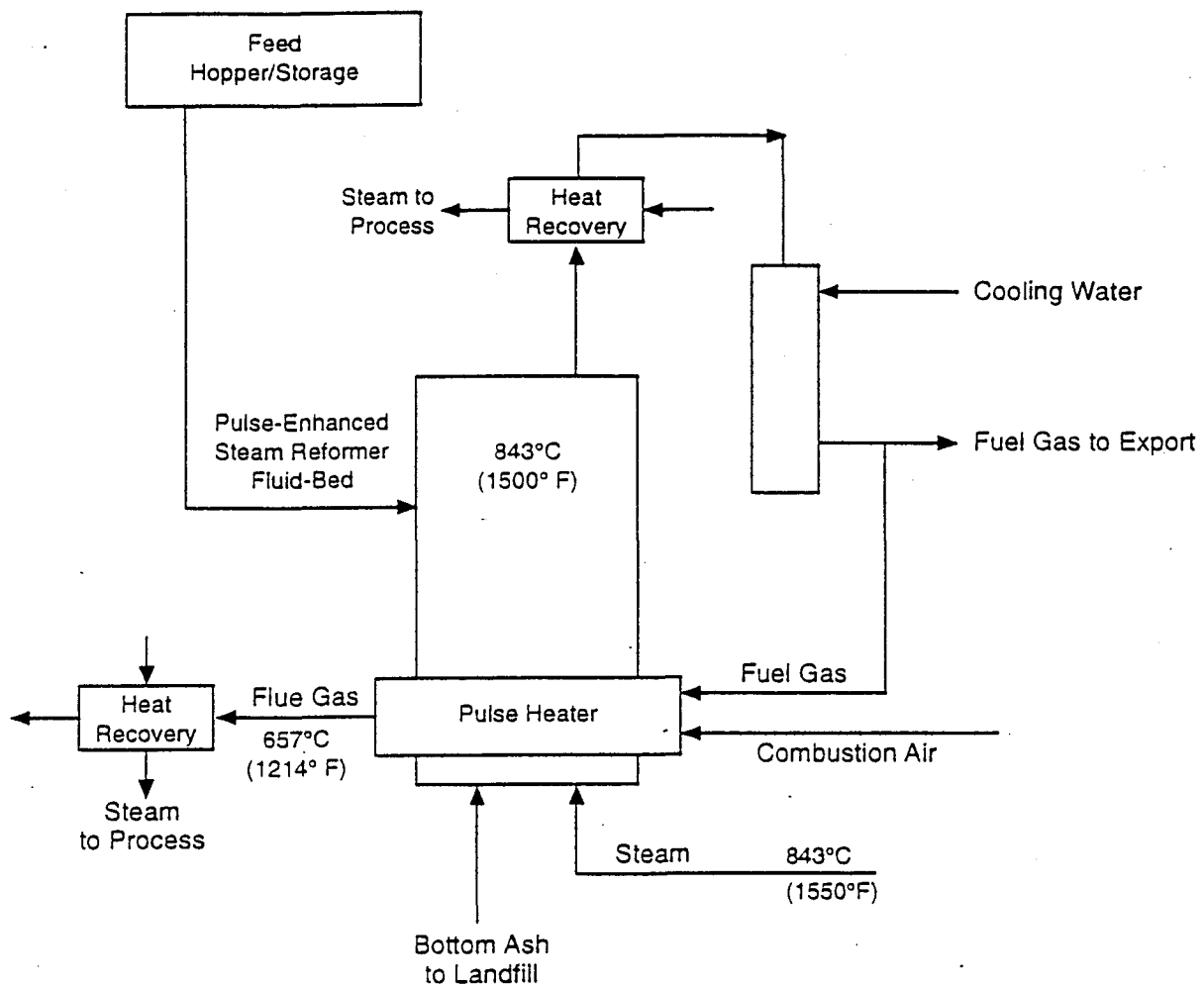


Figure 3. Proler Process Flowsheet







**R2**

**Challenging the Status Quo:**

**Innovations in MWC Ash Management**

## ***Challenging the Status Quo: Innovations in MWC Ash Management***

Douglas E. Sawyers, Malcolm Pirnie, Inc.

### **ABSTRACT**

Investigations into the feasibility of using municipal solid waste combustion (MWC) ash for beneficial purposes have resulted in the identification, development, and implementation of new, innovative, entrepreneurial management strategies. Historically, ash management has centered about the use of either monofill or co-disposal landfills. Landfilling ash can be looked upon as a loss of several potentially reusable materials; namely the ash itself and both ferrous and non-ferrous metals which are often inefficiently or not at all separated and disposed of with the ash. Additionally, landfill disposal has proven to be a costly management alternative due to increasing solid waste tipping fees at MWCs required to cover current ash disposal costs and costs associated with the development of future dedicated ash disposal capacity.

The emergence of beneficial use markets and improved economic viability of alternative ash management programs, in concert with changes in regulatory protocols that has introduced flexibility for expanding recycling and beneficial use programs, has been reflected in the consideration of these alternatives to landfill disposal. In addition to significant research completed regarding the environmental and physical feasibility of ash reuse (not addressed in this paper), there are a number of programs in several states, including Florida and Pennsylvania, that have successfully addressed these concerns. Many of these programs include the enhanced recovery of ferrous and non-ferrous metals and the reuse of ash as a landfill or other construction material.

### **INTRODUCTION**

Municipal solid waste is generally managed as part of an integrated solid waste management system. The components of this system often include waste reduction, reuse/recycling, energy recovery, and landfill disposal. As part of the solid waste planning process, managers routinely consider the impact of each unit activity on the overall waste management system. Historically, the management approach for MWC ash has centered about disposal of ash in monofill or co-disposal landfills. This practice was predicated on the popular opinion that ash is a potentially hazardous material that requires stringent management. As a result, regulatory programs restricting ash management alternatives were developed. To assess the feasibility of alternative management strategies, public and private entities undertook research initiatives to more accurately characterize the constituents of the ash and to evaluate and understand potential environmental risks associated with exposure to these constituents. The results of research, coupled with advances in ash treatment and processing technologies, promulgation of more flexible regulatory programs, and increasing economic responsibility associated with landfill disposal have supported the growth of beneficial use alternatives.

### **DEVELOPING ASH MANAGEMENT ALTERNATIVES**

The development of alternative waste management strategies requires that regulatory, technical, and economic issues or factors be addressed to fully assess the feasibility of any given program. Relevant concerns for beneficial use programs include:

beneficial use/reuse projects in Pennsylvania, including the use of Rolite, a Portland cement stabilized ash product as daily cover material and base material for on-site roads, several preliminary approvals for the use of untreated ash as daily cover, and the use of ash as a component, with other waste materials, in a grout product for use in mine reclamation.

Another example of this trend is the State of Florida with its enactment of the *Solid Waste Management Act* (Chapter 62 of the Florida Administrative Code) in 1988. This Act established requirements for waste management, recycling, financial responsibility, public education, research and development, and other activities. Like many other states, Florida has adopted USEPA guidance as the basis of its ash testing and characterization requirements. However, based on the quality of ash indicated by the body of ash characterization data, following *City of Chicago, et al., v. Environmental Defense Fund*, Florida modified ash testing requirements to consist of a one-time, 7-day ash characterization study to determine if the ash stream generated at a MWC would be classified as a hazardous or nonhazardous waste and monthly sampling and analysis for total metals. Additionally, ash is permitted by regulation to be used as daily cover at landfills which are permitted to accept ash for disposal.

Section 702.600 of Chapter 62 of the Florida Administrative Code provides the general requirements for the recycling or beneficial use of ash or processed ash. These requirements include a description of the proposed use, the physical and chemical properties of the ash or the ash product to be recycled, demonstration that the use will not impact surface or groundwaters (via Synthetic Precipitation Leaching Procedure (EPA Method 1312)), and that the recycled ash or ash product is substantially reused within one year of generation. It is also important to note that Florida allows the beneficial use of ash to be counted toward State-mandated County recycling goals. Increasing interest in ash reuse in Florida has prompted the formation of a Solid Waste Ash Committee comprised of municipal representatives from across the State and representation of the regulatory agencies to evaluate and help develop beneficial use opportunities. In addition, Florida is in the process of preparing an policy to serve as guidance for ash reuse programs statewide.

### ***Technical Issues***

Perhaps the most important question regarding the beneficial use of ash is related to the fate and transport of the potentially environmentally dangerous constituents, namely leachable heavy metals including cadmium and lead. This issue has been the focus of numerous research projects including a series of investigations conducted by the USEPA Risk Reduction Engineering Laboratory throughout the 1980s. Although waste characterization testing conducted by resource MWCs for disposal purposes has routinely indicated that combined ash is largely a nonhazardous material via USEPA-approved toxicity leaching tests (e.g., EP Toxicity or TCLP), various technologies have been developed to reduce the potential for leachability. One study by the USEPA evaluated several treatment processes/technologies designed to reduce leachability. These stabilization/solidification technologies were evaluated by TCLP as well as other leaching tests designed to target specific constituent release patterns under varying pH conditions. The data further indicated that treated ash products did not release constituents of concern (i.e., heavy metals) in quantities that would result in adverse effects on human health or the environment (Kosson et al., 1993). The results of private research were supported by several full-scale field demonstrations that ash could be successfully



**Table 2**  
**Currently Operating Ash Processing/Treatment Facilities**

<i>Vendor/Operator</i>	<i>Description</i>	<i>Location</i>	<i>Estimated Cost<sup>†</sup></i>
American Ash Recycling, Inc.	WES-PHix <sup>‡</sup> plus screening/sorting with materials recovery	Nashville, TN*	\$30-35
Resource Recycling, Inc.	Screening/sorting with materials recovery	Pinellas County, FL*	\$3-5
Rolite, Inc.	Portland cement addition	Minquadales, DE	\$25-35
Wheelabrator Environmental Systems, Inc.	WES-PHix (Phosphoric acid addition)	Licensed for use at more than 20 MWCs in the U.S.	\$3-8

<sup>†</sup> per ton of ash treated

\* AAR reports that it recently has obtained permits for its proposed facility in Scarborough, ME and have been selected to develop a similar facility by the Connecticut Resource Recovery Agency

\* Also has facilities in Key West, FL; Hempstead, NY; and Niagara Falls, NY.

<sup>‡</sup> Licensed from Wheelabrator Environmental Systems, Inc.

**Thermal Ash Treatment.** Thermal ash treatment technologies are based on the application of electric energy in the form of heat to raise the temperature of ash to its melting point and then cooling the liquefied ash into a stable, supercooled matrix (glass-like material). The heating and cooling of the ash bonds trace constituents on the atomic level. In 1990, the American Society of Mechanical Engineers and the U.S. Bureau of Mines initiated an investigation of the merits of vitrification as a waste treatment process, the results of which indicated that sixty-nine to 86 percent of the processed ash formed vitreous products, with the remainder forming metallic product, matte product, and fume, baghouse, and gas solids. TCLP testing of the vitreous products for the eight regulated metals indicated that concentrations were below regulatory limits. Additionally, the vitrified products met the ASTM requirements for Portland cement and asphaltic concrete aggregates (ASME, 1994).

Thermal treatment processes, with processing costs reported to run as high as \$200 per ton, have not been as economically attractive as the physical/chemical based alternatives. As thermal treatment technologies continue to improve, more favorable economics are expected to improve the overall feasibility of this type technology in the ash management field.

## **MARKETS**

Potential beneficial use applications for ash generally fall into one of two broad categories: (1) alternative landfill construction materials; and (2) substitute aggregates in asphalt and concrete products.

### ***Landfill Applications***

The beneficial use of ash on state-of-the-art MSW landfills is generally viewed as an acceptable alternative by the regulatory community given the landfill liner and leachate collection systems incorporated into these landfills and, hence, the reduced potential for environmental impact. The applicability of this alternative is largely dependent on local and state regulatory interpretation and requirements. The use of ash as an alternative landfill construction material reduces the added expenses of buying and transporting cover materials to the MSW landfill site, while using the ash in

The existence of many standard testing protocols and specifications for materials to be used in concrete applications and products provide a basis for addressing issues associated with obtaining regulatory approvals. The use of ash as a complete or partial replacement for natural aggregate in concrete mixtures requires that the product exhibit specific criteria for moisture, organic, fines, and glass content. These criteria may affect the curing and stability of the concrete. From a physical standpoint the product must demonstrate shear and compressive strengths to allow for its use in particular applications. Research in this area has indicated that ash aggregate content ranging from 15 to 50 percent have produced concrete products of acceptable physical properties.

### **IMPLEMENTING BENEFICIAL USE**

With over 9 million tons of ash generated annually at MWCs, the potential impact of beneficial use is significant (Berenyi and Gould, 1993). Although ash has consistently passed waste characterization testing, many solid waste managers have included treatment as a means to reduce the potential for leaching to protect against potential liabilities generally associated with landfill disposal and to encourage acceptance of ash as a reusable material. As beneficial use alternatives continue to develop additional data and experience will amend and enhance the already extensive body of information that substantiates the feasibility of reuse. The combination of actual field experience and regulatory oversight should serve to further address remaining environmental, technical, economic, and other issues.

Despite the success of beneficial use programs to date and the promise of greater acceptance by regulators, industry, and the public, beneficial use has been slow to emerge as an alternative to landfill disposal. Significant technical and analytical data exist which suggest that the beneficial use of ash is feasible and several beneficial use projects have been implemented and are currently operating in the United States. However, to a large extent, the solid waste industry has been slow to respond. To change our paradigm in ash management from landfill disposal to reuse options several factors must be understood and addressed.

First, as previously mentioned, many states do not have defined regulatory programs that are applicable to the beneficial use of ash, a waste that historically has been subjected to sensitive public and regulatory concerns. In light of apparent shortfalls in regulatory programs, in states where solid waste management officials have been proactive in the development of innovative ash management strategies regulatory agencies have recognized the benefit of beneficial use and have joined the regulated community to both support and participate in the development of innovative waste management strategies. In areas where regulators may not be fully aware of the history of ash reuse, solid waste managers must draw upon and stress the results of prior reuse investigations to validate their proposed programs and to reduce unnecessary returns to detailed analytical demonstrations.

Secondly, the maturation of treatment and processing technologies has only recently begun to impact this industry. As technologies continue to meet and exceed the stringent technical and operational specifications required by the solid waste industry, opportunities for beneficial use will become more readily available. Garnering support from regulators can be a key factor in gaining acceptance from industries that may be reluctant to use a material that, although shown to be technically acceptable, may be perceived as an environmental risk.



**No. 7**

**SAFGLAS**

**(Vitrification)**

Smaller investment and operating costs are incurred if the vitrification plant can be integrated in an existing industrial plant. In the case of vitrification of filter ash from municipal waste combustion (Figure 9), this is particularly easy to accomplish. The dusts are taken directly from the emptying devices of the boiler and the filter and can be delivered, still hot, to the preheater of the high temperature separation plant.

Intermediate storage of the problem material and the thereby associated danger of possible moisture uptake by the dry goods is eliminated.

The dust-freed waste gases from the converter plant constitute a small fraction of total flue gas volume of the waste combustion plant and can therefore be mixed in before the existing waste gas purification.

## SAFGLAS™

### OVERVIEW

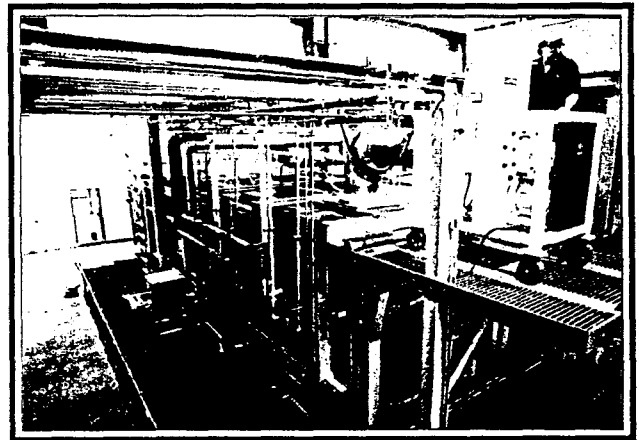
ATG's SAFGLAS™ system is a proprietary process which thermally destroys and stabilizes organic material through vitrification. Vitrification is an economic thermal destruction method in which the final waste is reduced to a solid glass. This waste form is acceptable at every commercial LLRW disposal facility in the United States and is considered throughout the world to be an environmentally superior waste form. This end product eliminates the need for further treatment such as compaction to prevent dispersability or solidification due to failing the EPA's Toxic Characteristic Leachate Procedure (TCLP) for acceptability at disposal sites. Volume reductions are similar to incineration and are in excess of 200:1. In addition, the SAFGLAS™ process is a more versatile thermal destruction technology in that a wider variety of heterogeneous waste streams and higher isotopic activities can be introduced safely into the system.

### Feed Material

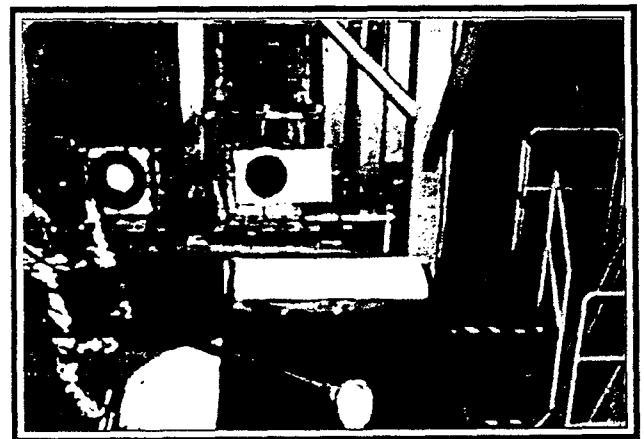
The SAFGLAS™ process is unique in that destruction and stabilization occur in one step. This is advantageous because SAFGLAS™ is a more flexible process and can handle heterogeneous waste streams such as dry active wastes (i.e., plastics, paper, wood, cloth, etc.), ion exchange resin, aqueous liquids and oils, filter media and sludges.

### Facility Description

The SAFGLAS™ facility is located at ATG's 45 acre Richland Operations in Richland, WA. The facility is approximately 11,500 ft<sup>2</sup> which includes a sorting and segregation area, the SAFGLAS™ process unit, the off-gas handling system, and the process support areas.



*View from the SAFGLAS™ Control Room.*



*SAFGLAS™ - 200 to 1 volume reduction with highly stable waste form.*

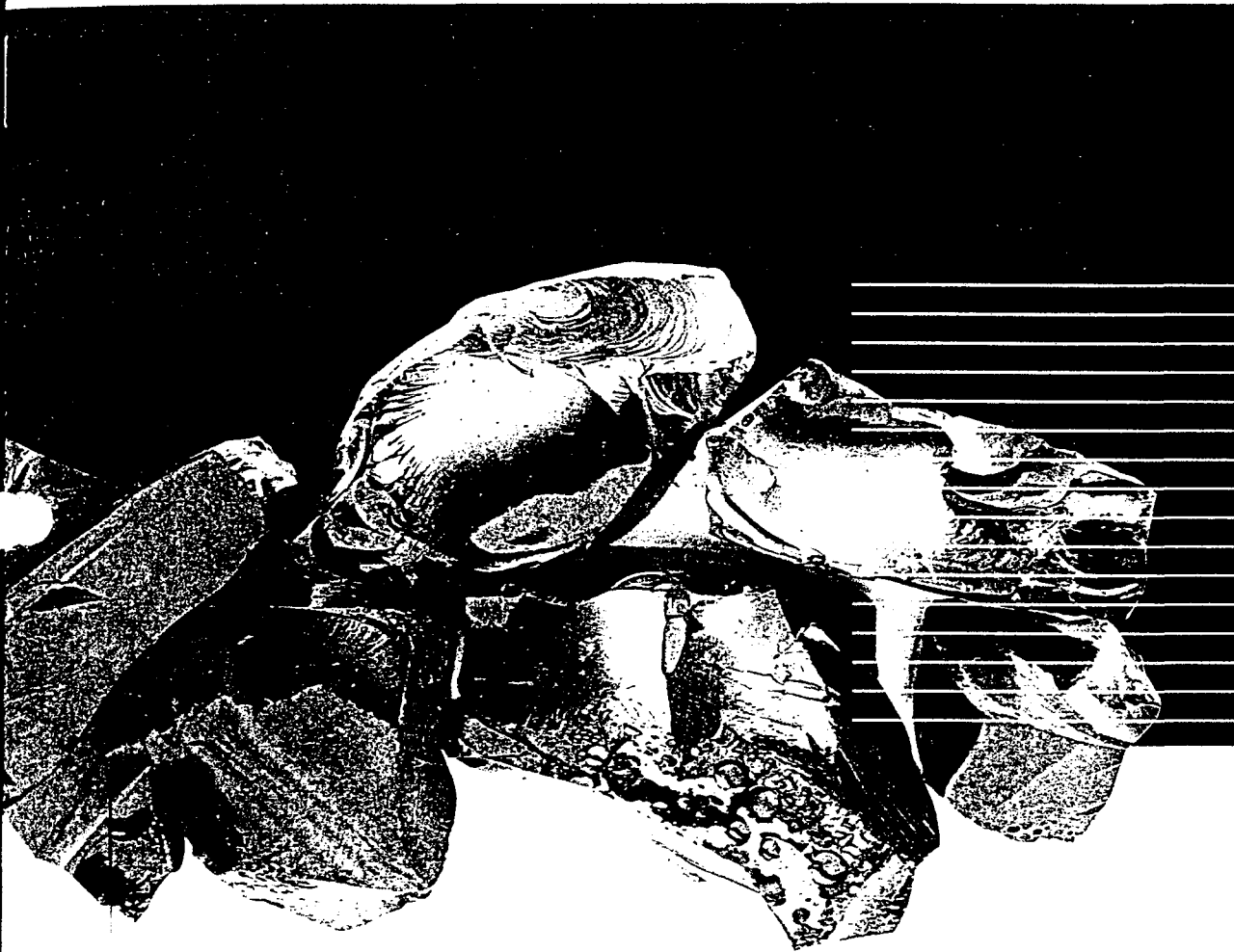
**No. 8**

**SEILER Glass**

**(Vitrification)**

# Seiler

ned into Glass  
A Solution for the Future



Non-Hazardous Glass Generated From Waste Using Seiler High Temperature Vitrification Process

SEILER

SEPC AG



## Contents

- 1 The Problem: Safe Disposal of Toxic and  
Other Hazardous Waste
- 2 The Solution: Transform Hazardous Waste  
into Safe Non-Hazardous Recyclable Materials
- 4 The Seiler Team: Experts in Environmental  
Processing
- 6 The Result: Commercially Viable Products
- 7 Seiler Experience Makes the Difference
- 8 Seiler Today

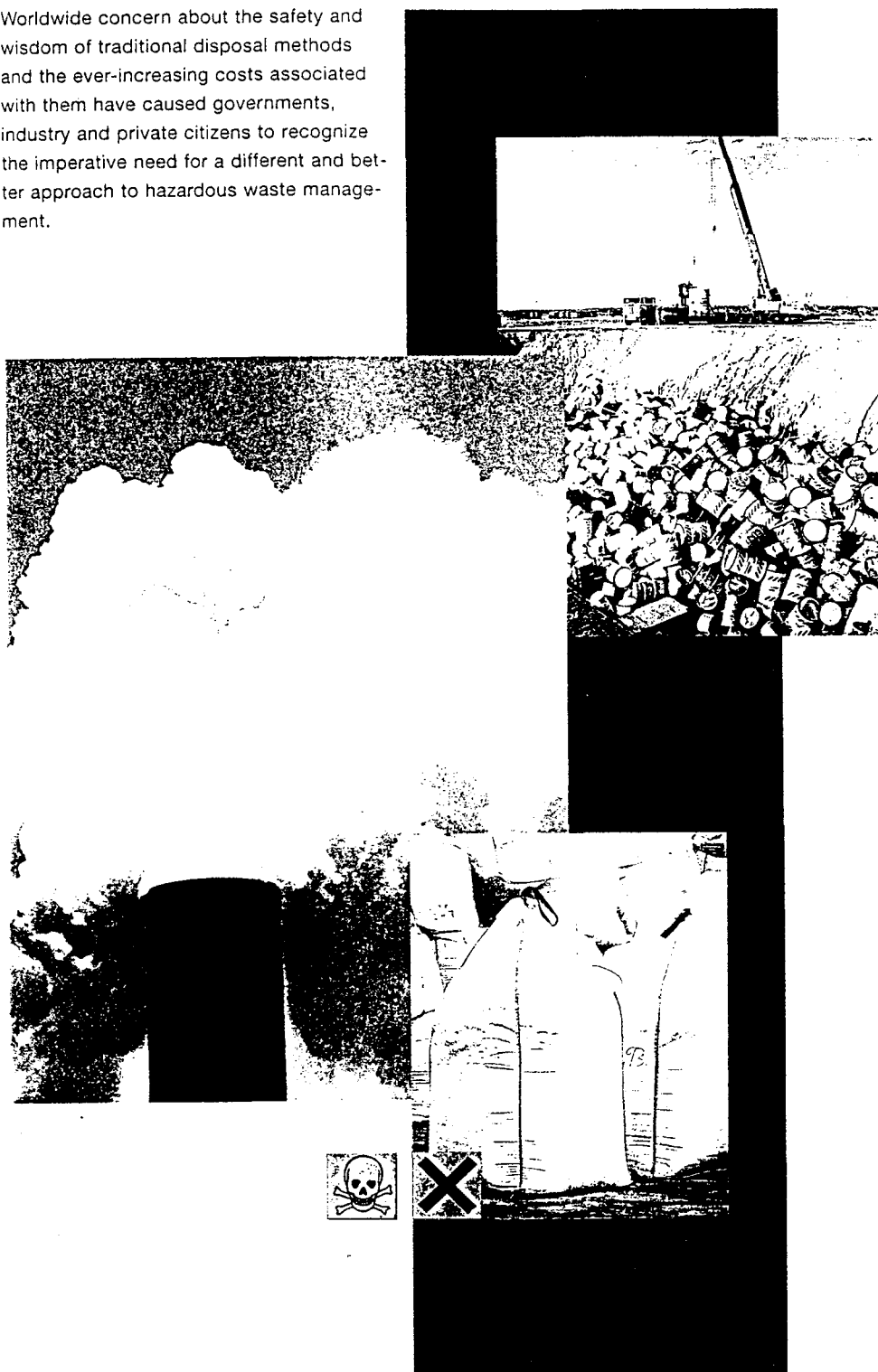
# The Problem: Safe Disposal of Toxic and Other Hazardous Wastes

For years, government and industry have faced the challenge of how to safely dispose of toxic and other hazardous wastes. Europe generates hundreds of millions of tons of hazardous waste each year. The United States produces over 300 millions of tons annually. The total amount of hazardous waste generated worldwide is unknown. Likewise and of greater concern, the method of disposing of much of the world's hazardous wastes is not known.

Historically, hazardous wastes were disposed by incineration, deposited in surface impoundment's, placed in landfills and sometimes stored in abandoned mines. All of these methods required close and continuous monitoring of the disposal sites to assure their security and safety.

Exporting wastes to other countries or between states within the United States grows increasingly more difficult and, in some cases, has even been prohibited. Heavy surcharges and high fees, as well as complicated governmental requirements, have been put in place to discourage or eliminate interstate and international hazardous waste transactions. Furthermore, permitting difficulties and diminishing disposal capacity in Europe and the United States have severely curtailed construction of new disposal sites and existing disposal space is rapidly filling up.

Worldwide concern about the safety and wisdom of traditional disposal methods and the ever-increasing costs associated with them have caused governments, industry and private citizens to recognize the imperative need for a different and better approach to hazardous waste management.



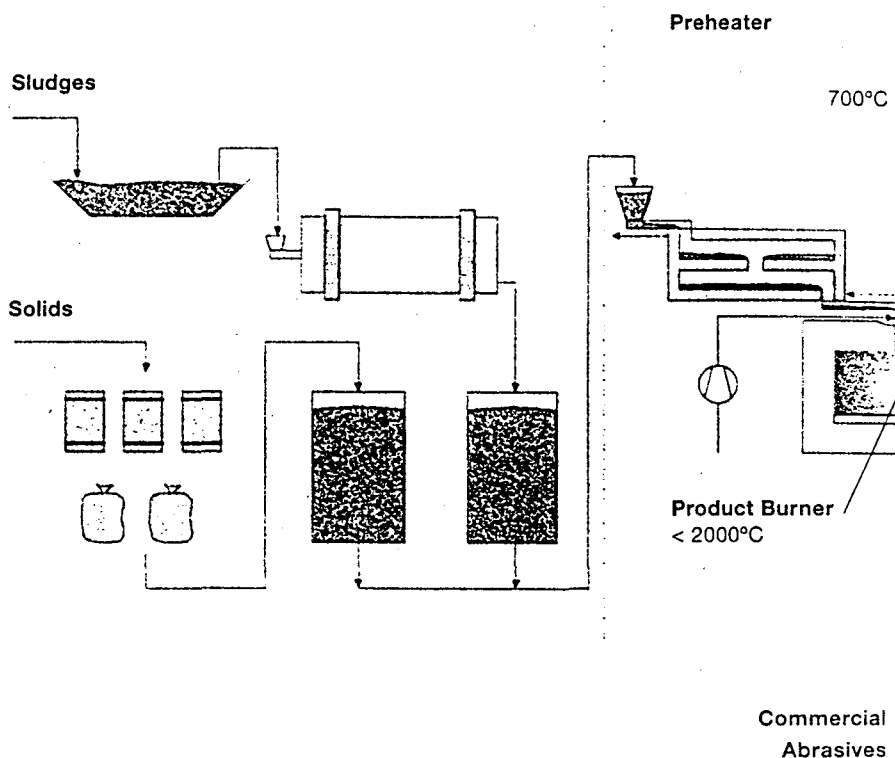
# The Solution: Transform Hazardous Waste into Safe Non-Hazardous Recyclable Materials

## Pretreatment, Drying

Seiler Pollution Control Systems Inc. has been on the cutting edge of toxic and hazardous waste processing for more than 10 years. Applying science to theory, Seiler developed an innovative technique that transforms hazardous wastes into safe nonhazardous recyclable materials through high temperature vitrification (HTV).

After several years of research, developments and testing, Niklaus Seiler headed a team that constructed the first pilot High Temperature Vitrification System in 1988. Since the initial start-up, significant refinements have been made in the system's electronics, linings and controls. Diverse hazardous materials have been successfully processed and tested over the years. Some of the materials tested were paint sludge, hydroxide sludge, slag's, electroplating sludge, incinerator ash, asbestos, sand blasting residues, lead glass, ammunition, battery wastes, neon lights, hospital wastes, contaminated oils, toxic sewage sludge, shredder light fractions from car shredders chemicals, mercury containing pesticides and many others.

Seiler expertise in hazardous waste treatment is evident in the ever-growing number of patents the company now owns. These include patent rights for: inductive medium-frequency vitrification systems; a barrel burnout installation for barrels with solidified waste; a double-piston pump; a hydraulic dosing pump for solid and highly viscous waste flows; a recycling system for lead batteries; and pyrolytic of aluminum from aluminum/plastic compound foils.



## Examples of Hazardous Feedstocks



Paint and Hydroxide Sludge



Industrial Wastewater Treatment Plant Sludge



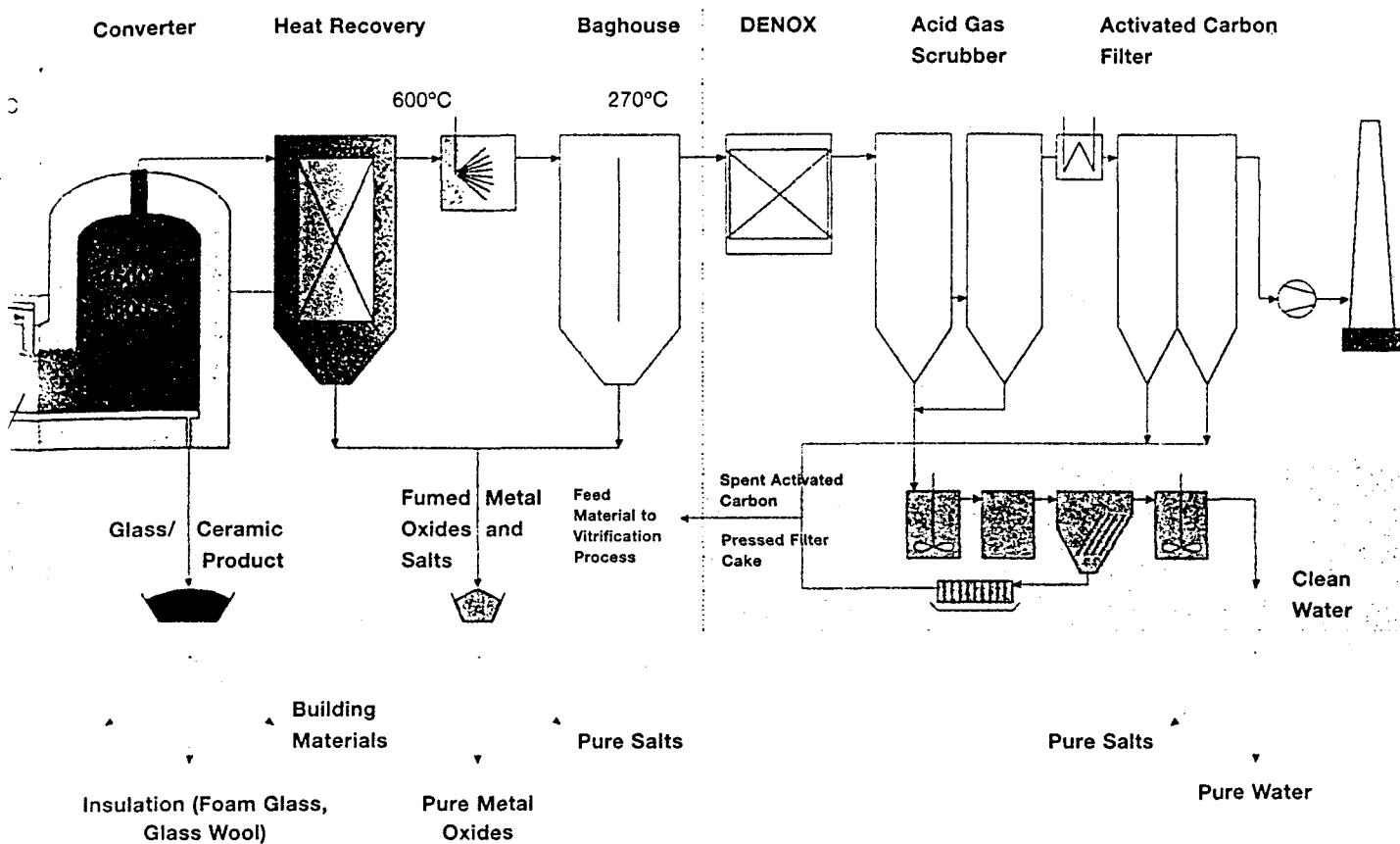
Electric Arc Furnace Dust and Hazardous Fly Ash



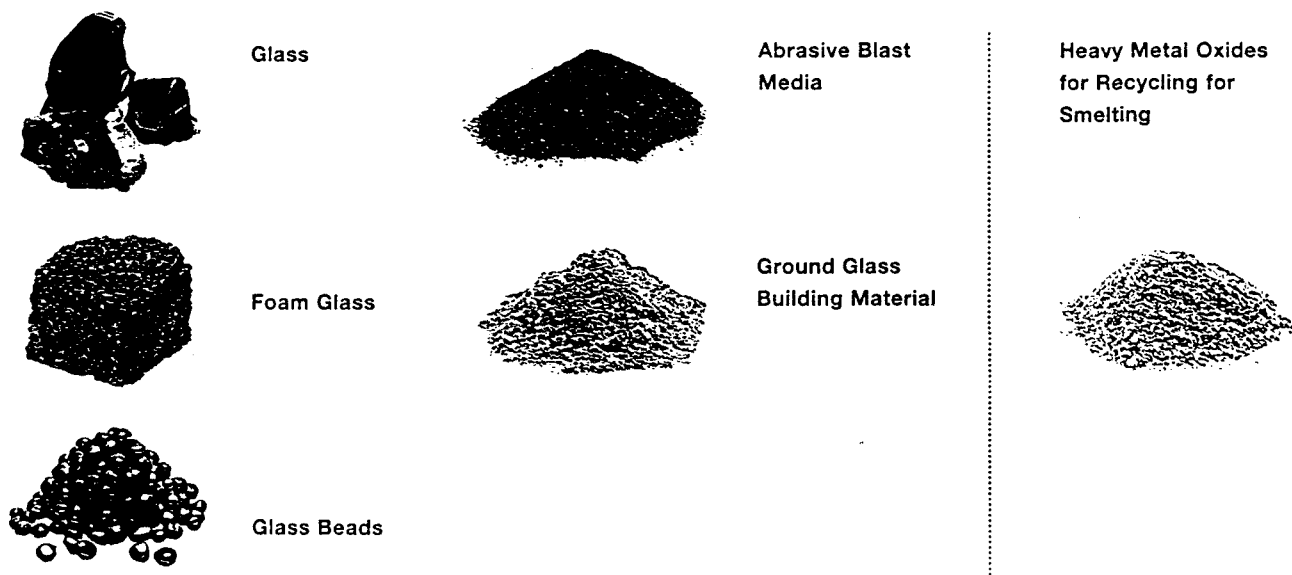
Toxic Gas, Pesticides and Organic Residues

## High Temperature Vitrification Plant

## Air Pollution Control System and Water Treatment



## Products from High Temperature Waste Vitrification



# The Team: **Experts** in Environmental Processing

Another Seiler accomplishment is the development of processing capabilities that prolong the refractory life of the high temperature vitrification components and lower maintenance requirements for a full commercial sized system. These are both areas where other environmental systems have failed.

Results confirm that the glass ceramics generated from the Seiler High Temperature Vitrification System meet or exceed United States Toxic Characteristic Leaching Procedure (TCLP) standards as well as similar European eluent (leaching) standards. Consistent glass ceramics produced from the Seiler Vitrification System had substantive hardness, toughness color and insulation properties for the commercial marketplace. Other reclaimable products were also generated such as metal oxides and salts. Flyash from incinerators were reduced in volume 30-40% and paint sludge were reduced in volume by 75%.

Seiler's HTV System renders hazardous wastes inert, nonhazardous and commercially reusable. The system can process a wide variety of industrial and governmental wastes. These include:

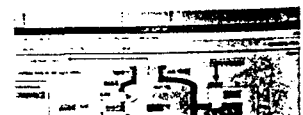
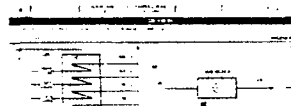
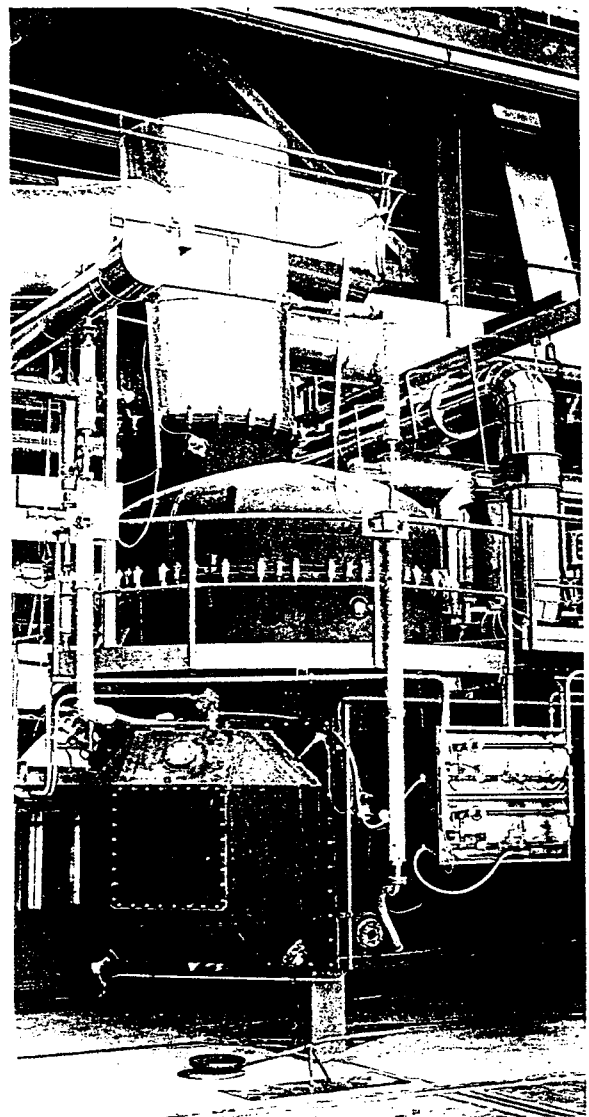
- Incinerator Fly Ash and Bottom Ash
- Paint Sludge
- Electroplating and Surface Finishing Residuals
- Wastewater Treatment Sludge
- Contaminated Chemicals, Petrochemicals, Spent Solvents, Oils and Pesticides
- Asbestos Containing Residuals
- Sand Blasting Residuals
- Electric Arc Furnace Dust and Other Steel Mill Residuals
- Mixed Organic and Inorganic Residuals

Seiler's High Temperature Vitrification Systems processes toxic and hazardous waste feedstocks through a multi-stage process. Vitrification is a process that

chemically and physically converts materials into glass substances by heat and fusion. The heart of the Seiler HTV System is a patented high temperature preheater and converter melter. Wastes are processed mechanically and thermally,

partly separated at high temperatures, and for the most part oxidized.

Unlike other environmental based technologies, the Seiler HTV System is compact, versatile and flexible. The system handles both dry and wet waste feed-





# The Result: Commercially Viable Products



Seiler's primary goal is to develop viable commercial products from waste feedstocks. Ceramics

and glass products are the primary recyclables created by the Seiler HTV System. Ceramics include any of a class of inorganic, non-metallic products which are subject to high temperatures during manufacture or use. Seiler glass ceramics have a variety of applications and uses; for example as construction materials, insulation materials or abrasive media.

Seiler believes the glass ceramic product area is in its infancy and envisions an exciting future for exploration of new applications and products for the HTV System from waste feedstocks. To fulfill its commitment to growth in these critical areas for the company, Seiler operates continuous research and development facilities in both the United States and Europe.

Utilization of Seiler's High Temperature Vitrification System offers the customer – and the world – a safe and sensible alternative for managing hazardous waste.

Because of the special characteristics exhibited by the glass ceramics generated by the Seiler System, the company has targeted three commercial product areas.

## The Architectural Market

This includes wall tile, floor tile, sinks and tubs, patio stones, mosaics, brick, block, vanities and counter tops. For this market, the waste feedstocks provide color, surface hardness and texture.



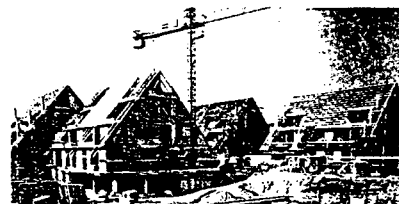
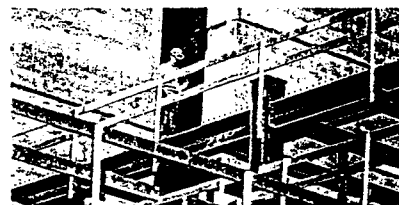
## The Abrasive Market

This includes sandpaper, grinding media, shot blast media, grinding wheels, glass beads, buffing compounds and polishing compounds. For this market, the waste feedstocks provide hardness, toughness and structural integrity.



## The Refractory (Insulation) Market

This includes fireproof wallboard, roofing media, foam glass, filtration media, high temperature speciality products and fiberglass insulation. For this market, the waste feedstocks provide insulating characteristics and thermal stability.



# Seiler Experience Makes the Difference



The origins of the Seiler Systems go back more than two decades. During all those years, the company's engineers and technicians acquired the expertise which has fed into the development of the Seiler vitrification process.

- 1969** Foundation of 'Seiler Montage und Apparatebau' Leibstadt/Switzerland.  
Assembly, starting-up, repair, service and maintenance of numerous hazardous waste incineration plants throughout Europe.  
Manufacture and sale of double-piston pumps to transport aggressive and pasty media.



- 1980** Initial trials with the gasification of different materials with the objective of reutilizing them without using extraneous energy:
- Recovery of steel, heavy metal oxides and carbon from batteries as well as lead from car batteries.
  - Recovery of aluminium, carbon and oil from compound foils as well as silver and tin from printed circuit boards.
  - Recovery of gases and oils from domestic and hazardous waste.

These recycling processes leave residues, some of which are toxic. In order to process these residues, too, a start was made in 1984 to vitrify them.



- 1987** Scientific proof of the successful vitrification of filter dust and paint sludge.
- 1988** Construction of the pilot vitrification plant in Leibstadt.  
Start of comprehensive tests with different heating systems and linings which are resistant both to high temperatures and to hazardous waste.
- 1992** Foundation of 'Seiler Hochtemperaturen-Trennanlagen AG' (SHT AG), Leibstadt, Switzerland.  
Planning, construction and assembly of Seiler Systems.
- Foundation of 'Seiler Patent AG', Risch/Switzerland. Management of the Seiler licences and patents.
- 1993** Foundation of 'Seiler Pollution Control Systems Inc.' Ohio/USA as a public corporation listed on the Nasdaq.
- Foundation of 'Seiler Pollution Control AG' (SEPC AG), Zollikon/Switzerland. Group Holding Company.
- 1994** Foundation of 'Seiler Hochtemperaturen-Trennanlagen Vertriebsges.m.b.H.', Baden/Austria.  
Planning, construction, assembly and starting-up of flue gas cleansing and wastewater treatment plants.
- 1995** Foundation of 'Seiler Trenn-Schmelzanlagen Betriebs G.m.b.H.', Freiberg/Germany.  
Operating company for the recycling of heavy-metal containing hazardous waste.
- 1996** World première of the first Seiler plant for the vitrification of toxic hazardous materials and their conversion into commercially viable raw materials in Döttingen/Switzerland.



# Seiler today

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## Seiler Hochtemperatur- Trennanlagen Vertriebsges.m.b.H. Baden/Austria

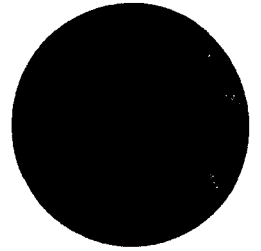
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The production company for  
flue gas cleansing installa-  
tions, as well as the sales  
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**Papers Presented  
at the  
Demonstration  
of the First  
Commercial High Temperature  
Vitrification System**

**June 27, 1996  
Dottingen, Switzerland**

SEILER POLLUTION CONTROL SYSTEMS, INC.

## Corporate strategy of SEPC

In 1969 the Seiler brothers established a fabrication and equipment company which assembled, maintained and repaired hazardous waste incinerator plants throughout Europe. It was from these beginnings that the vision of handling hazardous waste by converting these substances to glass as a safe and permanent solution was conceived.

Years of research and development work followed at substantial cost. In 1987, Niklaus Seiler successfully vitrified fly ash and plant sludge residue. One year later the first Seiler vitrification pilot plant was constructed. For the next five years significant changes were made to upgrade the system. During this time several pilot tests on different waste feedstocks for various industrial facilities were performed.

Because of the success of the pilot facility and the widespread interest, it had attracted during this five year testing phase, the Seiler management decided to build a commercial vitrification system and to market it internationally. This step was a decisive one because it required an increase in system capacity, staff and additional funds. It goes without saying, it is virtually impossible to raise risk capital for such a project. While some major groups expressed considerable interest in funding the Seiler technology, this inevitably would have meant that the existing Seiler management would have lost its independence and control. It was therefore decided by management to take the Seiler technology public and place it into the United States NASDAQ stock market. By doing this, management, to date, has been able to raise substantial funds to pursue Seiler's commercial goals and therefore solve a major funding problem, as well as maintaining control. In the Spring of 1993 Seiler Pollution Control, Inc. became a U.S. public company. Over 25 million SF in equity has been raised jointly with investors and the Seiler family.

Today, the Seiler Companies employ more than thirty people, the majority of which work in the Canton Aargau, Switzerland in the project planning and production departments. Other staff are involved in the manufacture of flue gas components in Austria. While still others are working on the development of projects in Germany and North America. This team is supplemented by other entities which make a considerable contribution to the planning and production capacities of Seiler. Some of these include:

Cerm Anlagenbau, an engineering company which specializes in project design and planning of waste incineration facilities for companies such as Von Roll, W&E Martin, etc.

Erne Metallbau, a metal fabrication firm in Leuggern

Hensel & Co., Zurich, designer and manufacturer of electronic switchgear

Radian Incorporation, a subsidiary of Dow Chemical, USA, Seiler's general contractor on US Airforce project

The Ohio State University Department of Materials Science and Engineering, an academic institute which provides research, development and scientific expertise for product development with state-of-the-art laboratory facilities for bench work.

Because of the capabilities of the Seiler staff and world class support team, it is Seiler's goal to construct and operate 15 commercial scale vitrification systems within the next two years. This represents a turnover of more than 100 million SF. These turnover forecasts are based on firm declaration of intent from more than twenty industrial and governmental customers from Europe, North America and the Middle East. Final negotiated contracts are contingent upon the commissioning and trouble free operation of the Seiler commercial system presented to you today.

The Company through its Board of Directors has planned specific long term strategies. Potential markets for Seiler vitrification facilities worldwide have been identified. Factors considered in their identification process were specific waste streams needed, product markets, state of industrialization and economics. Because of the hazardous waste volumes developed, based on current worldwide estimates, the Company has projected that over 15'000 Seiler commercial processing systems or similar environmental answers will be required within the next five years. If we make a conservative assumption that Seiler's aim is to cover merely 2% of this potential market volume, then over 300 Seiler vitrification facilities will be needed.

To take up this enormous challenge it will be necessary for Seiler to not only significantly grow its own infrastructure, but also to enter into joint ventures with established industrial partners who already have a substantial infrastructure. Negotiations are already underway in this respect. It will be also a primary priority in the coming months to redefine Seiler's future corporate structure more clearly so that we can timely implement these goals.

Finally, we need to focus on potential future areas for applying the Seiler commercial vitrification process. We have done preliminary research and are convinced that the Seiler technology can be used for stabilizing low-level radioactive mixed wastes. These materials continue to plague hospitals, research institutes and governmental agencies. Our aim will be to develop the Seiler commercial System for this area by working with the responsible agencies, hospitals and institutes in order to solve these ongoing problems. Another ecologically sensitive area that we are looking into is the disposal of chemical and bacteriological wastes. The research and development in this area is in its infancy. However, because of the significant worldwide problem in handling these materials, the potential growth for Seiler can be substantial.

We are proud to be able to present to you today a solution to a significant number of worldwide environmental problems. The Seiler commercial vitrification system is ecologically sound and makes economic sense. We know that the entire Seiler team will face a great number of challenges in the near and long term future. In this sense, we see today as an important first step in the continuing efforts to protect our environment.

# **The Seiler High Temperature Separation Process**

By Dr. Gerold Weser, Vice President SEPC European Operations

## **Introduction**

Handling of hazardous wastes such as paint sludges, electroplating sludges, hydroxide sludges, asbestos containing materials, chemicals, and incinerator ash and slag residues are an ongoing problem. Current practices of landfilling these materials or placing them in old abandoned mines is problematic both ecologically and politically. Past treatment technologies have been an incomplete answer. They either have temporarily postponed the problem for other generations to handle, or simply exchange one form of pollution for another. Disposal options are dwindling. Laws are being implemented throughout the world that force hazardous waste generators to handle their wastes in the country and area where they are produced. For example, a law of this very kind has been implemented this past year in Switzerland which will prohibit the disposal of Swiss wastes outside of Switzerland (the Basel Agreement).

The Seiler High Temperature Vitrification System is a process that can convert hazardous waste into usable commercial grade products. The process will bind heavy metals from the waste feed into a glass ceramic matrix where they form an inert, nonhazardous compound that cannot be separated under ordinary environmental conditions. This process generates glass ceramics which are similar to heavy metal bearing silicates found in nature.

Although the glass ceramics produced from the Seiler system will pass governmental leachate disposal standards in both Europe and the United States. Seiler's policy is not to dispose of these materials. Products such as concrete cement feedstocks to improve road surfaces and other building products can be produced because of the hardness and toughness of the glass ceramic compounds. Sand blasting media can be produced because of the abrasivity of the glass ceramic compounds. Foam glass can be produced because of the insulating properties of the glass ceramic compounds. What was once a harmful array of pollutants, can now be a means to resource conservation and recovery.

## **History**

In 1988, after several years of research and development, Niklaus Seiler, with the

help of several of his family members, built the first Seiler Vitrification Pilot Plant in Leibstadt, Switzerland. For the next few years, this pilot facility had to overcome several difficulties that plagued other similar environmental systems, such as refractory life, feed problems because of the different types of wastes it needed to handle, material exit problems due to the viscosity and temperature differentiations, burner problems because of the varying calorific values of the waste feeds, and many others. One by one these problems were addressed, and the Seiler pilot system went through several changes. Since the beginning of 1992, the Seiler pilot system has been in constant operation, and has successfully processed several thousand tons of the most varied hazardous materials. Lead based materials, ammunition, asbestos, hydroxide sludges, incinerator flyash, sand blast residues, paint sludges, wastewater treatment sludges, and several other wastes were all tested in this system.

Building on these tests and experiences, the first Seiler commercial system was constructed. The Seiler commercial system incorporates all of the knowledge of the pilot with the practicality of several environmental specialists for processing real waste feedstocks for working industrial and governmental entities.

### **Description of the process**

The Seiler Vitrification System is a high temperature melting technology, utilizing natural gas, air, and oxygen as its primary energy source. In areas where it is economically impractical to use natural gas, propane or fuel oil can be substituted. As a supplementary energy source, the system uses high calorific waste feedstocks. The system integrates other important components, including feeding equipment, drying equipment, a patented preheating system, a waste heat recovery system, a complete off-gas treatment system, and state of the art computer controls. The waste feedstock input capacities for this system are currently rated at 250 - 500 Kg's per hour (6 - 12 tons per day), but the Company believes that these rates can be exceeded. All the described plant components are coordinated with each other, and for the most part have been specifically developed for this process.

#### **1. Pretreatment and drying**

Waste materials are initially placed in a feeder hopper where they are ground down to size. A screen prevents undesirable materials from entering the system. Wastes with moisture contents greater than 20% by weight are transferred into a

rotary dryer that is capable of drying material down to a 5% moisture content. Total energy load and process rate is adjusted to assure consistent output.

## **2. Preheating**

The dry waste feedstock is then fed into the preheater where the materials are preheated indirectly with hot air to approximately 600 - 800 degrees C. During this process, volatile organics are gassified and injected into the vitrifier converter where they help supplement energy requirements through a special product burner. The heated inorganics are augered or swept into the converter separately, where they are used as the primary source for the glass ceramics generated by the system. The preheater allows for increased waste handling versatility because of its capabilities for handling mixed organic and inorganic feedstocks. It is a sealed system.

## **3. Converter**

The preheated materials and volatile gasses are delivered to a refractory lined glass tank operated at temperatures between 1500 - 1600 degrees C. The converter is temperature controlled in zones, and is equipped with oxygen injectors at the burners. The feedstock which were introduced are completely thermally decomposed in an oxidizing atmosphere. The bulk of the heavy metals and other inorganics collect at the bottom of the converter in an homogenous molten mass. Because of the extreme temperatures, some of oxidized metals and salts become gaseous and leave the converter with the other flue gasses. Organic materials, including dioxins and furans are shown to be completely destroyed at these temperatures.

The converter operates on a continuous basis and is the heart of the Seiler system. As soon as a specific volume of molten glass has been generated at the bottom of the converter, the glass will run over a weir and will exit the system. The exit system is set up with various devices which will provide for different glass ceramic forms depending upon the specific commercial application that is desired. For example, there is a glass bead maker, a water bath to develop granules, or there is room to place a spinner to make glass fibers.

## **4. Heat Recovery**

Prior to the flue gasses going to the off-gas treatment components, the gasses from the converter are cooled in a multi-stage heat exchanger. In this system,



the gasses are cooled from 1500 - 1600 degrees C down to 600 degrees C. Most of the thermal energy produced is recycled back to preheat the combustion air or to heat the preheater. The remaining thermal energy can be used elsewhere in the system such as in the dryers. The salts and metal oxides which condense in this temperature range are captured and placed in airtight containers for recycling and/or future reclamation.

## **5. Dioxin Trap**

In order to prevent any formation of dioxins during the cooling process (De Novo synthesis), the flue gas is abruptly cooled from 600 degrees C to approximately 250 degrees C.

## **6. Off Gas Treatment System**

All of the following components make up the Seiler Off Gas Treatment System. These components may or may not be required depending upon the materials being processed. The air pollution limits applicable to the Seiler system are based on the Austrian, Swiss and German "pure gas" regulations.

### **Particulate and Metal Oxide Baghouse**

The flue gas is sent through Teflon clad filter bags which separate out the salts and metal oxide particulate. These materials arise as a dry crumbly powdery substance. These materials are either recycled back through the system or are collected for their reclamation value.

### **Catalytic Denitrification**

While flue gas temperatures are maintained between 250 - 280 degrees C, a 14% weight ammonia solution is sprayed into the gas stream ahead of catalytic elements which enhance conversion of Nox to N<sub>2</sub> and water.

### **Wet Scrubber**

Flue gasses are further cooled from 250 degrees C to 73 degrees C in a water quench chamber intended to remove HCl and HF. The gas is then scrubbed with sodium hydroxide to remove SO<sub>2</sub>.

### **Activated Carbon Filter**

A carbon filter designed to capture small quantities of dioxins, furans, and mercury is installed after the scrubber. Flue gas is reheated to 135 degrees C to maximize adsorption efficiency. Residues including spent carbon and additional particulates are neutralized, filtered and recycled back through the system.

### **Wastewater Treatment System**

The Seiler system also has a mini wastewater treatment system for those facilities that do not have one. Water discharges are collected in a modular waste treatment system which is designed to precipitate, settle, filter, and remove pollutants collected from the off gas system. Wherever possible the process water is recirculated to the air pollution control equipment. Treatment plant solids are recycled back to the vitrification process.

### **High Calorific vs Low Calorific Handling**

Depending upon the specific waste materials, more or less primary energy will be required. One of the greatest achievements of the Seiler Vitrification System is the fact that the system burners automatically adjust for this factor which accounts for extremely efficient processing capabilities.

For example, when vitrifying paint sludges from the automobile industry, only 2.6% of the entire thermal energy used in the converter is needed from the primary source (natural gas, fuel oil or propane). Approximately 30% of this energy is also used as waste heat (in the form of hot air) which can be used to preheat other streams or to dry other wet sludges. Vitrification of filter ash from incinerators, however, presents quite a different picture. In this case approximately 70% (1650 kwh / t) of additional heating energy from the primary energy source is required. Approximately 20% of the waste heat produced from this stream can be reutilized. The Seiler System is unique in that it offers the possibility of mixing feedstocks with high and low calorific values to optimize the use of primary energy. This was successfully accomplished in several tests.

### **Summary**

The Seiler High Temperature Vitrification System is a unique environmental processing system that can handle a wide variety of waste feedstocks. The system is versatile in that it can handle both wet and dry materials as well as mixed

organics and inorganics. Unlike the environmental systems that have come before it, it does not trade one type of pollution for another. The final result from this system are commercially viable products that have been developed from materials that are no longer needed or wanted. The Seiler System not only promotes pollution prevention but also promotes resource conservation and recovery.

## Glass and Glass - Ceramic Products Manufactured from the Seiler Vitrification System

By Prof. Charles Henry Drummond III., Ohio State University

The manufacture of salable commercial products from industrial waste with high disposal costs promises to revolutionize waste disposal. Industrial waste, such as electric arc furnace dust, waste water treatment sludge, fly ash and electroplating waste can be made into high grade abrasives, roofing granules and architectural materials using the Seiler system. Hazardous materials containing heavy metals, such as chrome or lead, may be rendered safe by incorporation into the glass - ceramic structure, providing superior product characteristics such as hardness or color. What makes this possible and how is it accomplished?

Glass has long been recognized as a very stable and durable material, for which there are many examples. Glasses melted by Egyptians two or three thousand years ago are still in their original form with only minor surface attack. Stained glass windows designed and produced in medieval times are still bright and clear. Naturally occurring geological glass is stable for millions of years with very good chemical durability. Some important modern, technological applications for glass and glass - ceramics, where the stability and chemical durability are critical properties, include containers for pharmaceuticals, chemical glassware and glass used for the disposal of nuclear waste.

Chemical durability of glass is defined as the resistance offered by a glass towards attack by aqueous solutions and atmospheric agents. The mechanisms involved in the leaching of heavy metals, the usual materials of concern, include ion exchange of the hydrogen ion,  $H^+$ , from the aqueous solution for alkali or the heavy metal cations in the glass. This may be followed by attack of the leached layer by hydroxide in the aqueous solution with the dissolution of the glass matrix.

Research conducted by graduate students in the Department of Materials Science and Engineering at Ohio State University in Columbus, OH, USA has been directed towards developing compositions for glass and glass - ceramic products to be manufactured in the Seiler vitrification system. This research is being supported by industry and government in the State of Ohio through a research grant for the Edison Materials Technology Center. More than twenty Ohio companies are providing assistance developing these products. The next step in this program will

be the construction of a pilot plant to process industrial waste and develop new products.

Glass compositions developed for Seiler at Ohio State University contain a high percentage of acidic oxides such as  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{Cr}_2\text{O}_3$  which result in high chemical durability. Of the basic oxide additions, most are divalent cations ( $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{ZnO}$ ) which have also been shown to increase the chemical durability of silicate glasses. The monovalent alkali oxides such as  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$ , which tend to reduce chemical durability, are present in only small amounts. Glass compositions for the Seiler vitrification system have been developed to minimize the concentration of basic oxides and maximize the concentration of acidic oxides.

A glass's molar basicity is defined as the number of moles of basic oxides divided by the number of moles of acidic oxides. A molar basicity of 1.0 implies a neutral glass, while a molar basicity less than 1.0 is acidic. Once the composition of the glass is determined, the molar basicity of the glass can be calculated and can be used as a useful parameter to predict chemical durability. It is desirable that the glass be acidic for increased chemical durability. Thus, some of the metals, such as chrome and iron, will improve the chemical durability of the glass. The calculated molar basicity of Seiler vitrified products is typically less than 1.0, making these formulations quite acidic and therefore highly resistant to long - term leaching.

Another parameter which has been used to predict the chemical durability of glasses is the free energy of hydration. The free energy of hydration is a measure of a glass component's tendency to undergo the hydration (dissolution) reactions by which the ions are leached into the solution. Large positive values of this parameter imply that the component is stable and will undergo these dissolution processes at a very slow rate. Negative values of this parameter imply that the reaction is favorable and will proceed rapidly. The more negative the free energy of hydration, the more soluble this oxide will be in the leachant. A glass which has a large positive free energy of hydration is likely to have excellent chemical durability. In addition to high acidity, these formulations are quite high in oxides with positive values of the free energy of hydration ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ) and for those oxides which do have negative values, only the most durable oxides are represented in significant amounts ( $\text{CaO}$ ,  $\text{MgO}$ ). The Seiler compositions are similar to naturally occurring basaltic glasses with near zero or positive heats of hydration and have been shown to have excellent chemical durability. This fact offers further evidence that these formulations should maintain excellent long - term chemical durability.

Another important aspect of the compositions developed for Seiler vitrified products is that they are designed to crystallize out specific crystalline phases which have certain desired properties, such as hardness, and at the same time incorporate into their structure certain of the hazardous materials, such as heavy metal cations. One of the particularly useful phases is the crystal spinel which has a general chemical formula,  $AB_2O_4$ . This crystal will accommodate a large number of different metals over significant ranges of solid solubility into its structure. The spinel phase is also extremely chemically durable. Since the heavy metal cations occupy lattice sites in the structure in order to leach these cations, diffusion through the lattice is required.

It is important to understand that glasses and glass - ceramic materials have atomic structures that are maintained when the particle size is reduced. Furthermore, factors controlling the properties, such as chemical durability, remain the same no matter what the size of the particles. The structure of Seiler vitrified products is the same no matter how finely divided. This is in sharp contrast to other processes, such as encapsulation, in which the hazardous material is coated by some other material. In this case, smaller particles will not have a complete coating and hence the hazardous elements can be easily leached. The vitrified products produced by Seiler do not result in encapsulated material. The hazardous materials are molecularly bonded into the glass and glass - ceramic structures. The properties of these materials are the same no matter what the size of the particles.

Another important aspect of the Seiler vitrification system is that the process is expected to accommodate a variability in the composition of the waste feed stocks being fed into the system. Adjustments can be made to produce the same composition for the final product. The quantities of the additives can be changed and the amounts of the different feed stocks adjusted to correct this variability. In addition, the glass and glass - ceramics maintain their same properties, such as chemical durability, even as the compositions change. In the case of glasses, the solubilities of various oxides are great enough so that increases and decreases of the concentration of a particular component are not expected to significantly change these properties. In the case of crystalline phases, such as spinel, the solid solution solubility of various components can also accommodate the changes in feed stock compositions. Thus, the process variability of the Seiler vitrification system and compositional flexibility of glasses and glass - ceramics is expected to accommodate changes in waste feed stock compositions to produce a product which will provide acceptable chemical durability.

Seiler vitrified products are compositionally tailored to minimize the leachability of hazardous materials. These glass compositions contain a high percentage of oxides which increase the chemical durability. The crystalline phases formed also have extremely high chemical durability and molecularly incorporate heavy metals, such as chrome, into their structure. These properties are retained even when ground to fine particles. Based upon current scientific knowledge and existing references, the compositions developed by Seiler have been optimized to produce materials expected to retain hazardous components, such as chrome oxide, for long periods of time under normal atmospheric conditions.

# HIGH TEMPERATURE PROCESS FOR THE SEPARATION OF HAZARDOUS WASTE INTO AN ELUTION-RESISTANT GLASS PRODUCT AND CONCENTRATED HEAVY METAL DUST

Erwin Wachter and Niklaus Seiler

Seiler Hochtemperatur-Trennanlagen AG, Switzerland

## Summary

In the Seiler process hazardous waste is disintegrated and to a large extent oxidized at a high temperature. This results in the production of a glass-like, hard and elution-resistant material. On the other hand heavy metal oxides and neutral salts separate out in concentrated form and from these the pure metals can be recovered. By mixing with organic high calorific starting materials, the primary energy requirement for the process can be reduced to a minimum. As is shown by means of examples, the high temperature separation plant can be built either as an independent unit on a green field site or integrated in a plant with existing flue gas and waste water purification.

## Introduction

The disposal of hazardous waste is, from an ecological and political viewpoint, becoming increasingly difficult. The guidelines in Switzerland for coping with these materials stipulate for the future that these problem producing materials must be dealt with where they are produced. The currently existing practice of moving hazardous waste into disused mines or surface waste dumps in foreign countries will therefore not be possible for much longer. Rational treatment steps for solving this problem must therefore be found.

The Seiler High Temperature Separation Technique provides a process which can be used for transforming hazardous wastes into reusable useful materials. In this process the problem materials are disintegrated and to a large extent oxidized at a high temperature. This results in the production of a glass-like, hard and elution-resistant material which can be reused as a basic component in the cement industry, in road construction to improve the coating layer, as sand blasting sand or in other fields. On the other hand, heavy metal oxides and neutral salts separate out in concentrated form and from these the pure metals can be recovered in the smelting industry.

The manufacture of glass is a thousand year old skilled art and today statements can be made about its long term behaviour to an extent not applying to any other material. The large scale technical production of a vitrifying plant for specific hazardous wastes, however, usually fails because of the service life of the fire-proof materials or because of practical problems.

The Seiler pilot plant was developed and built in 1988 based on experience with other vitrifying systems. Since 1991 it has been continuously subjected to a high temperature and has successfully vitrified various problem materials such as enamel coagulate, paint or hydroxide sludge, filter ashes from municipal solid waste incineration plants, asbestos residues, used sand blasting sand and many more. Not least because of the long working



life of the test plant, several large plants have been ordered, of which the first is being built at the moment.

### Description of the process

Figure 1 shows the high temperature separation process itself. All the components of the plant described have been designed to match one another and for the most part specially developed for this process.

#### *Preheating*

The dry starting material to be treated is removed from a surface silo and delivered by a screw conveyor to a buffer container of the preheater or degassifier. Additives for the vitrification process are mixed in as required. The amount and the composition of the necessary glass-forming material depends on the required quality parameters of the product. The dry goods are then preheated indirectly in the preheating unit by hot air at ca. 600 - 700 °C. With this process volatile organic components are set free in the absence of air.

#### *Converter*

The products of degassing emerging from the preheater have a high calorific value and are burned with air or oxygen in a special product burner and supplied together with the residual pyrolysis solids to the converter. If there are insufficient energy rich components in the starting material, the process can be supported with fuel gases (propane, natural gas, etc.).

In the vitrifying furnace the materials supplied are completely decomposed thermally at ca. 1'500 - 1'800 °C in an oxidizing atmosphere. The largest part of the oxidized heavy metals and also the salts produced are gaseous at this temperature and emerge from the converter, together with the combustion gases being formed, through an afterburner chamber. The low volatility components collect at the bottom of the converter in a molten state. Under the conditions existing in the reaction chamber, and as a result of a suitable molten mass delay time, when it is drained out a glass-like inert material is produced.

Organic substances, such as aromatic and polycyclic hydrocarbons, and any dioxin and furan that may be present, are demonstrably completely destroyed at this temperature.

The converter operates continuously and consequently, in operation, stationary conditions occur in all plant parts connected upstream and downstream from it. On start-up or change of the material introduced, as soon as a predetermined liquid volume has been reached in the converter, the glass runs out continuously through a special "to be melted" outlet and is removed through a cooling device designed to be suitable for the product (cooled conveyor belt, waterbath, etc.).

#### *Heat recovery*

The waste gas from the converter is cooled in a multi-stage air/flue gas heat exchanger from a temperature of 1'550 °C to 600 °C. On safety grounds a water quench cooler is connected in series with the heat exchange inlet.

Part of the thermal energy produced (hot air at 400 - 850 °C) is required for heating the degassifier and for preheating the combustion air. The remaining part can be used in other ways (e.g. in-house services) or leaves the plant through a hot air chimney.

The salts and metal oxides, which condense out in this temperature range, are removed with a screw conveyor and loaded into sealable containers.

### *Dioxin trap*

In order to exclude the formation of dioxin during the cooling process (de novo synthesis) as much as possible, the exhaust gas is cooled down abruptly in a water quench cooler from 600 °C to ca. 250 °C.

### *Dust removal*

The exhaust gas, cooled to ca. 250 °C, is led over a bag filter equipped with flexible teflon pipes which has three separate chambers. Two of them are always in use, the third is cleaned by compressed air in the closed-off state, so that the fine dust can settle in the funnel without exhaust gas movements. This results in a further separation of salts and heavy metal oxides which occur with a powdery, crumbly consistency. These enriched concentrates with a low specific weight (ca. 0.1 kg/dm<sup>3</sup>) are discharged by means of a compartmented wheel and loaded into sealable containers for further processing.

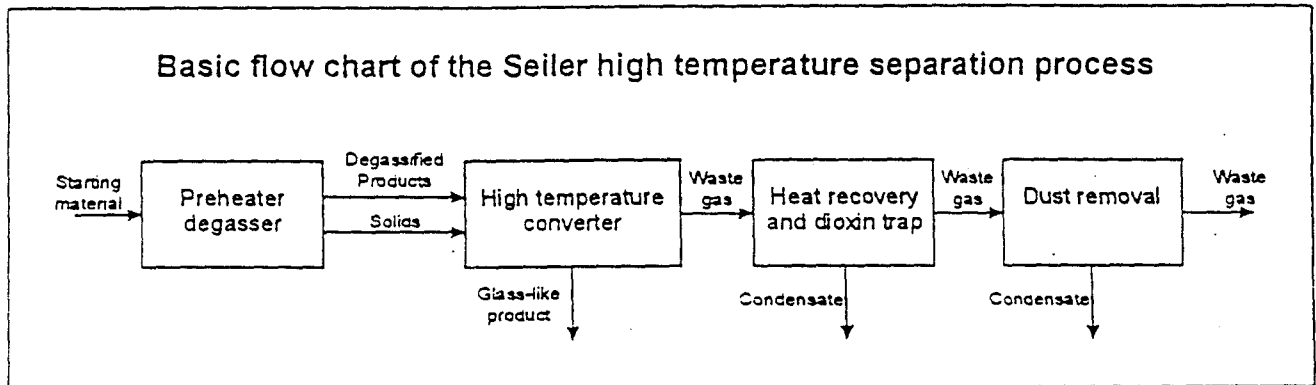


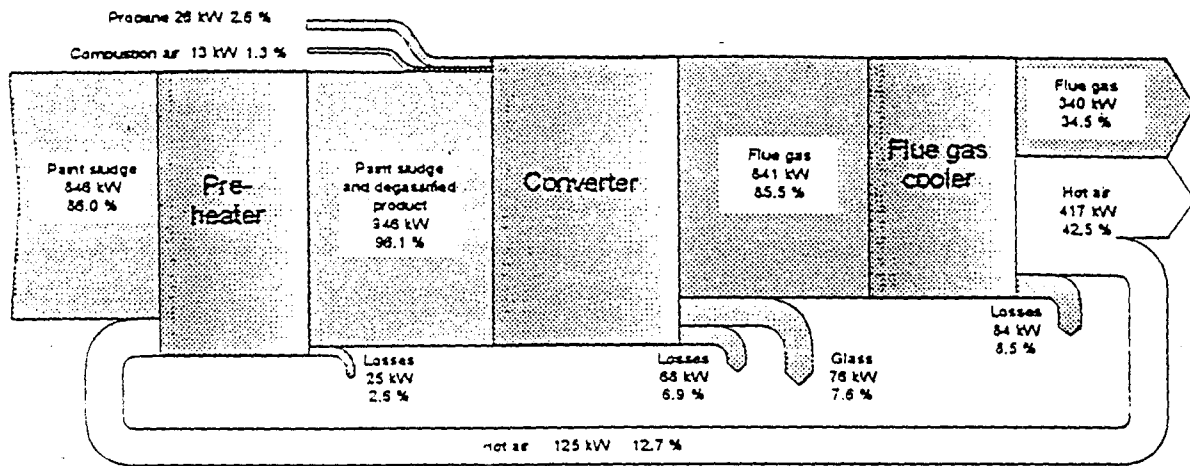
Figure 1: High temperature separation plant

### **Materials with high or low organic content**

Depending on the starting material more or less additional energy is used. As Figure 2 shows, in the vitrification of paint sludge from the car industry only 2.6 % of the total amount of the thermal energy converted in the converter is used in the form of additionally supplied primary energy. About 30 % occurs as waste heat in the form of hot air and can be used, for example, for drying the wet sludge.

It is different in the case of vitrifying filter ash from municipal waste combustion plants (Figure 3). In that case, because of the low calorific value of the problem material, ca. 70 % or 1'650 kWh/t of additionally required energy is utilized, and ca. 20 % can be used again as waste heat.

### Energy balance for a conversion plant processing 250 kg/h paint sludge

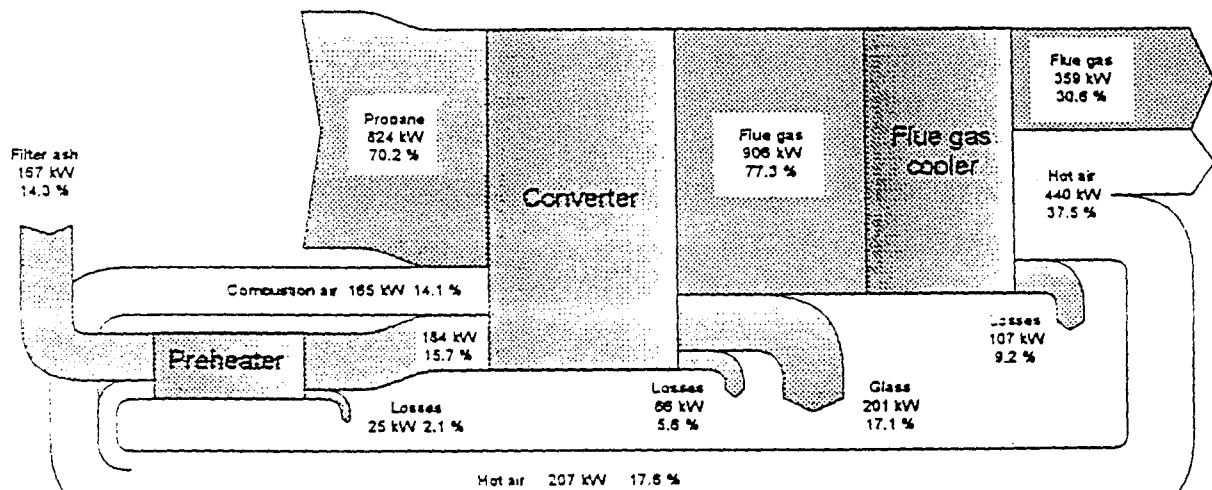


1. The energy figures are calculated as percentages of the total amount of energy transformed in the converter
2. The condensation heat from steam in the gases is not taken into account

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Figure 2: Energy balance with high calorific value material.

### Energy balance for a conversion plant processing 500 kg/h filter ash



1. The energy figures are calculated as percentages of the total amount of energy transformed in the converter
2. The condensation heat from steam in the gases is not taken into account

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Figure 3: Energy balance with a low calorific value material

From these considerations the possibility of mixing low and high calorific value starting materials arises, in order to optimize the amount of energy to be used. In this connection it can be said as a rough guide that above minimal energy values of 10'000 to 12'000 kJ/kg it is possible to operate the system almost without primary energy. Materials with high organic contents are therefore very suitable for the process on operating cost grounds.

### Properties of the glass-like product

As Figures 4 and 5 show, the amount of glass produced depends directly on the composition of the starting material. For example, the glass fraction from the filter ash with a high inert material content is ca. 65 %: from the paint sludge with a high organic content it is ca. 46% of the oxidized problem material. The condensate proportion is directly related to the heavy metal and halogen concentrations in the starting materials. It consists substantially of enriched heavy metal oxides PbO, CdO, ZnO, CuO) and alkali salts (NaCl, KCl).

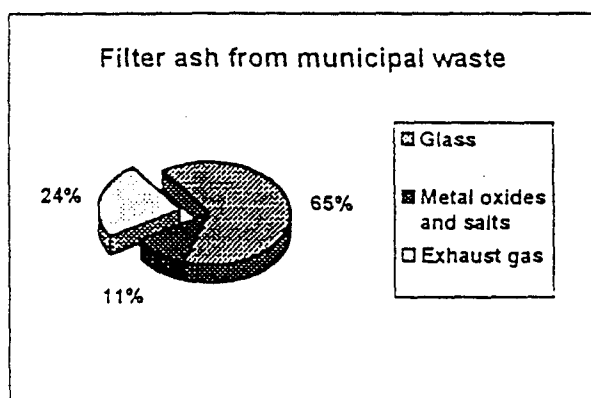


Figure 4: Fractionation in the case of filter ash

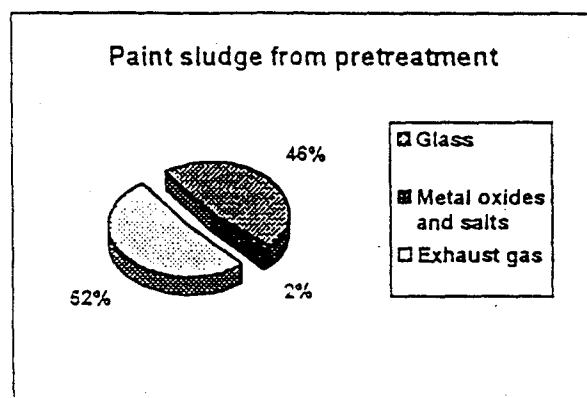


Figure 5: Fract. in the case of paint sludge

As studies in Switzerland and Germany have shown, the fraction of important glass forming elements (Si, Al and Ca) in filter ash from municipal waste burning plants is always sufficiently large. This fact is also confirmed by the analysis shown in Figure 6 of the glass produced. During pretreatment of the paint sludge, the coagulation agents are appropriately adapted so that during vitrification the desired composition is accordingly produced (Figure 7).

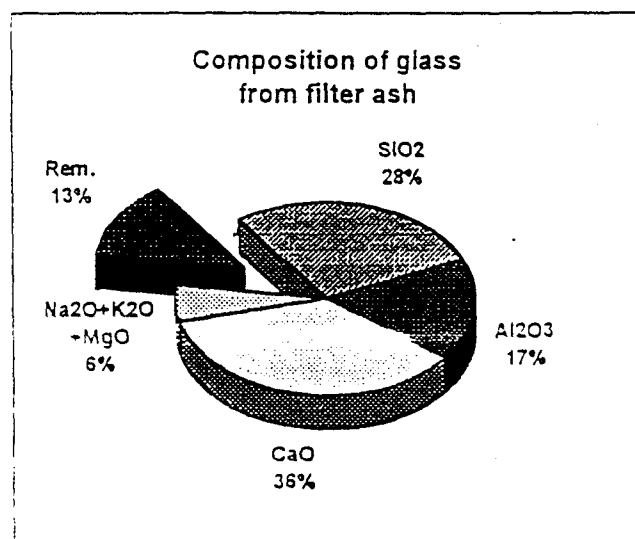


Figure 6: Composition of filter ash

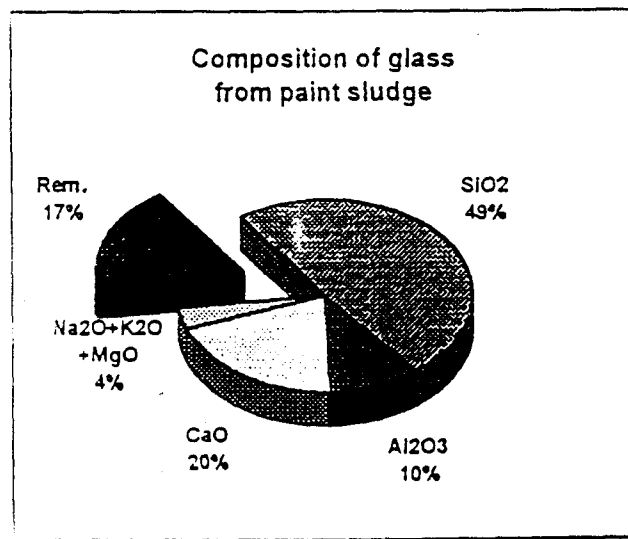


Figure 7: Composition of paint sludge

The resultant glass-like product has a shiny surface and a black basic colour and is distinguished by being very hard. Remaining heavy metals are permanently bonded in the glass matrix and no longer present any danger to the environment. A study of the elution value according to the strict Swiss standards (TVA) gave the analysis values shown in Tables 1 and 2 which are mostly below the detection limit, although the glass granulate had to be very finely milled in the first preparation stage.

<b>Technical Specification for Waste (TVA)</b>			
<b>for inert materials (Position Jan. 1st 1993)</b>			
<b>Starting material: paint sludge</b>			
<b>Elution values with distilled water:</b>		<b>Limit value</b>	<b>Glass analysis</b>
Ammonia / ammonium	[mg/l]	0.5	0.03
Cyanide	[mg/l]	0.01	n.n.
Fluoride	[mg/l]	1.0	0.57
Nitrite	[mg/l]	0.1	n.n.
Sulphite	[mg/l]	0.1	n.n.
Sulphide	[mg/l]	0.01	n.n.
Phosphate	[mg/l]	1.0	n.n.
Soluble organic carbon compounds (DOC)	[mg/l]	20.0	n.n.
Hydrocarbons	[mg/l]	0.5	n.n.
Organic Cl compounds	[mg/l]	0.01	n.n.
Chlorinated solvents	[mg/l]	0.01	n.n.
pH-Value	[-]	6+12	4.7
<b>Table 1</b>			

Except for the failure to maintain the pH-Value, according to this analysis all elution values were considerably below the limit values both with distilled water and also with carbon dioxide (in an acid medium).

Elution values with carbon dioxide:		Limit value	Glass analysis
Aluminium	[mg/l]	1.0	0.28
Arsenic	[mg/l]	0.01	n.n.
Barium	[mg/l]	0.5	0.11
Lead	[mg/l]	0.1	0.011
Cadmium	[mg/l]	0.01	0.0013
Chromium-III	[mg/l]	0.05	n.n.
Chromium-VI	[mg/l]	0.01	n.n.
Cobalt	[mg/l]	0.05	n.n.
Copper	[mg/l]	0.2	0.08
Nickel	[mg/l]	0.2	0.013
Mercury	[mg/l]	0.005	n.n.
Zinc	[mg/l]	1.0	0.16
Tin	[mg/l]	0.2	n.n.
Table 2			

The glass product can therefore unhesitatingly be used for various applications. If one considers the heavy metal concentration in the paint sludge starting material shown in Table 3, then it can be seen that this glass fulfils all the necessary requirements for the inert material class. The absolute metal contents in the glass matrix, however, depends strongly on the concentrations in the starting material. Relatively non-volatile oxides, such as NiO and ZnO, can not be completely distilled off at the prevailing converter temperature and partially remain in the molten mass. For specific applications elemental analyses and experiments in the pilot converter provide for particular starting materials the required parameters for the glass quality.

Technical Specification for Waste (TVA)			
for inert materials (Position Jan. 1st 1993)			
Starting material: paint sludge			
Heavy metal limit values:		Limit value	Glass analysis
Lead	[mg/kg]	500	5.2
Cadmium	[mg/kg]	10	0.02
Copper	[mg/kg]	500	44
Nickel	[mg/kg]	500	6
Mercury	[mg/kg]	2	0.02
Zinc	[mg/kg]	1000	34
Table 3			

## Plant design

If a vitrification plant is built on a greenfield site, then much more extensive waste gas purification stages must be designed to go with it, which are necessary to be able to comply with local legal regulations (relating to clean gas and waste water). In the case of a paint sludge treatment plant (Figure 8) these are in essence:

- a NO<sub>x</sub> removal plant with a catalyst and ammoniacal water as the reducing agent (SCR process) for reducing the nitrous oxide content
- a two stage flue gas scrubber for washing out HCl, HF, SO<sub>2</sub> and heavy metal residues
- a waste water treatment plant for neutralization and precipitation of heavy metals

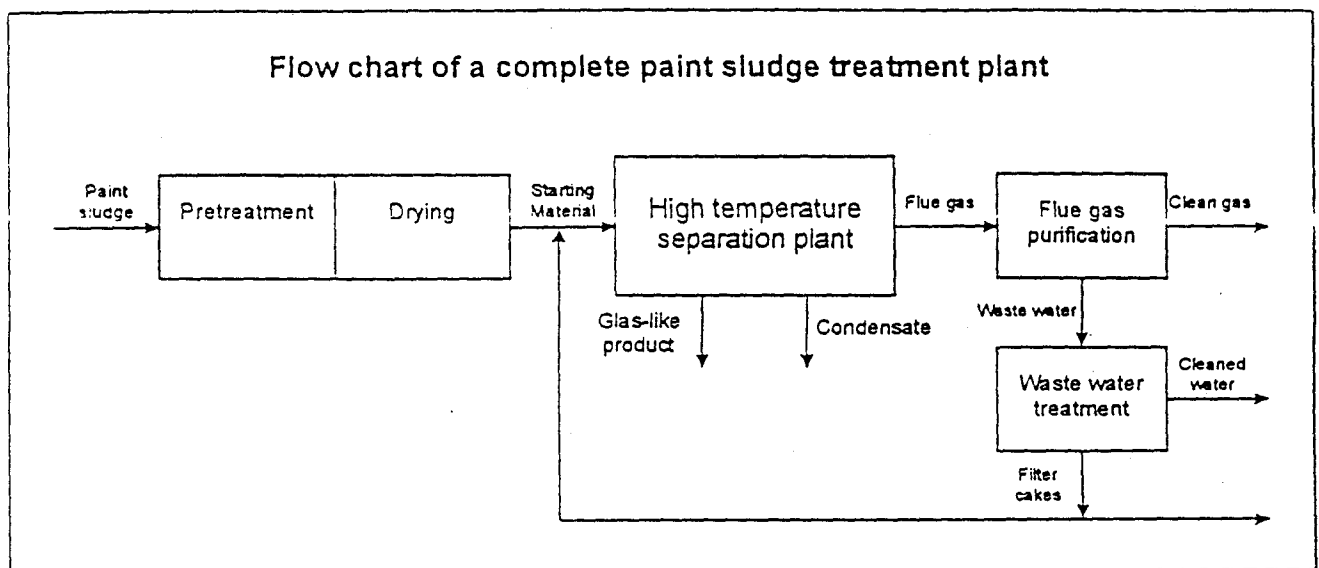


Figure 8: Independent plant

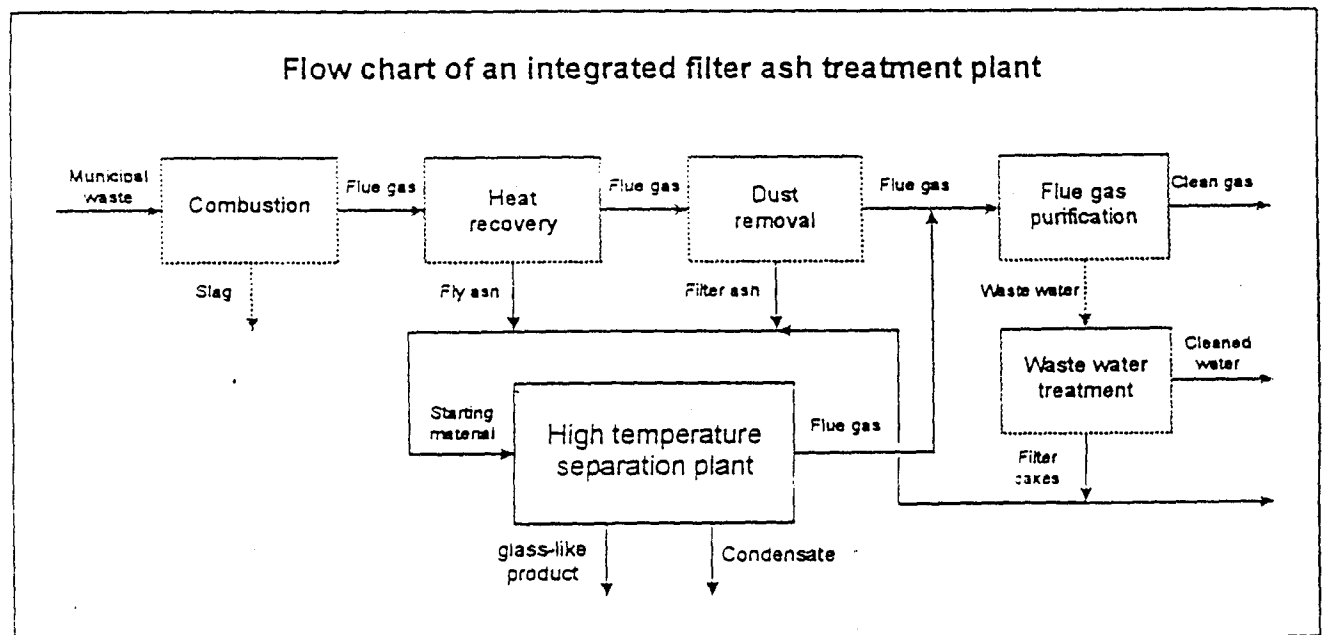


Figure 9: Integrated Plant

## **Seiler Pollution Control System's Incorporation - North American Market & Strategy**

By Alan B. Sarko, Vice President North American Operations

North American environmental markets are very competitive and regulatory sensitive, and will require a unique approach in order for the Seiler High Temperature Vitrification System to be accepted. Seiler's uniqueness lies in its system versatility, its ability to handle a wide variety of waste feedstocks, and its capability of producing commercially viable products that use the properties of the waste feedstocks as functional assets.

Within the next three years, Seiler North America will approach the following waste producing markets:

1. Wastewater Treatment Sludge Producers (governmental & industrial)
2. Paint Sludge Producers (governmental & industrial)
3. Electroplating & Surface Finishing Residue Producers (governmental & industrial)
4. Industrial Incinerator Ash Producers
5. Industrial Electric Arc Furnace Dust Producers
6. Sand Blasting Residue Producers (governmental & industrial)
7. Industrial Petrochemical Residue Producers
8. Foundry Sand Residue Producers
9. Low Level & Mixed Radioactive Waste Producers (governmental & private)

These wastes will be found in the auto/transportation industry, the defense industry, the chemical industry, the paint industry, the appliance industry, the computer and chip manufacturers, the electroplating and surface finishing industry, and in government clean - up and industrial sites.

Regulatory permitting for handling these waste materials can take as little as six months or as long as two years or more to complete. Every Seiler system at every North American site will need some kind of permitting, and construction cannot begin at a site without the permit activities finished. Seiler has a significant advantage in this area because its technology warrants a permit recycling



exemption. Some key components of attaining this exemption status is to assure that the product produced is a real product, and that the waste feedstocks used provide significant properties for that product. If the waste feedstocks are considered not to be necessary, then the processing activity will be considered as sham recycling and not qualify for exempt permit status. In the United States, unlike Europe, if recycled materials are strictly made for use on the land, such as for road base or fill materials, these materials are not exempt as this is considered a use constituting disposal. The activity of processing these types of materials is therefore subject to the hazardous waste permit rules.

Seiler's recycled products are ceramics and glass. Ceramics are defined as any of a class of inorganic non - metallic products which are subject to high temperatures during manufacturing or use. These materials include natural raw materials and a variety of manufactured or synthetic materials. Silica based ceramics can be used in all aspects of society, from basic construction materials to high - tech electronic computer chips. Glass products are included in the ceramic industry because they share many of the same raw materials, unit operations, processes and technologies as other ceramics.

Industrial ceramic production is subject to a cyclical durable goods market which necessitates cooperation with the changing requirements of the market place. The sale of industrial ceramics has grown to more than 800,000,000 tons per year. Natural raw materials make up only 4,300,000 tons of the total ceramic marketplace and are declining. The industrial ceramic marketplace has revenues which exceed \$ 10 billion (US Dollars).

Seiler qualifies for recycling exempt status because the glass/ceramic products generated from the vitrification system are produced for real commercial purposes with well established specification requirements. The product markets currently established for these materials are:

1. The Architectural Market – This includes wall tiles, floor tiles, sinks and tubs, patio stones, mosaics, brick, block, vanities, and counter tops. For this market, the waste feedstocks provide color and crystal structure.
2. The Abrasive Market – This includes sandpaper, grinding media, shot blast media, grinding wheels, glass beads, buffing compounds, and polishing compounds. For this market, the waste feedstocks provide hardness, toughness and crystal structure.

3. The Refractory (Insulation) Market – This includes fireproof wallboard, roofing media, foam glass, filtration media, high - temperature specialty products, and fiberglass insulation. For this market, the waste feedstocks provide insulating characteristics and crystal structure.

Therefore, for the Seiler process to retain exempt recycling status from the North American regulatory community, it is very much dependent upon developing real commercial products, and how those products are used.

Product development is integral for securing Seiler's success in North America. It is for this reason that Seiler has developed a significant alliance with the Ohio State University and its Department of Materials Science and Engineering. Ohio State is an international leader in the field of glass/ceramics, and provides Seiler not only with a research base for expanding into different glass/ceramic product areas, but also provides Seiler with sophisticated laboratory equipment to analyze and characterize various waste feedstocks and their resultant glass/ceramic products. Ohio State is one of the primary sponsors for the international glass conference which is attended by industrial concerns from all over the world.

With Ohio State, Seiler was awarded a project from Edison Materials Technology Center (EMTEC) to develop glass/ceramic products from waste feedstocks generated by Ohio industry. This project is scheduled to run for two years commencing October, 1995. It is funded by the State of Ohio with additional in - kind matching funds from Ohio industry. Some of the industrial partners on this project include General Motors, Delphi Chassis Division; Armco Steel; Columbia Gas Company; East Ohio Gas Company; Allis Minerals; Radian International; and Dunron. EMTEC is part of the Edison Institute of the State of Ohio and is charged with pooling Industry, Academia, and Government resources to make innovative products and systems.

Seiler has established a specific program to introduce its high - temperature vitrification technology into North America. All customers will go through laboratory testing and pilot testing before a formal commercial scale processing contract is executed. These previous test requirements allow Seiler to establish a formal data base for formulating and processing specific waste feedstocks. This not only helps to establish a customized system for each customer, but also helps to establish equitable pricing and data to facilitate regulatory considerations. Seiler will charge each customer for these tests to recover the costs incurred. Some of the expenditure incurred can be applied to building a full - scale system.

Most contracts in North America will be structured as operational tolling agreements, where the customer will pay a per ton throughput fee which will cover all costs including labor, utilities, amortized capital, maintenance, overhead, and profit. Typical contracts will run for 5 - 7 years with options to renew. Contracts will require minimum guaranteed waste inputs. Seiler vitrification systems are set up to run 7 days per week, 24 hours per day. It is estimated that it will require a minimum of 12 - 15 employees to operate the system for the year. If the customer cancels the contract at any time during the contract period, other than for Seiler's negligence, then all system capital costs will immediately become due and owing. This sales practice is consistent with the North American industrial practice which prefers experts handling waste and environmental concerns rather than having industrial facilities handling an area for which they are unfamiliar.

In certain instances, Seiler North America will consider an out right sale of a system. However, in this instance, an ongoing maintenance and licensing contract will be required for the customer to continue using the system on an annual basis. In most all cases, recycled product sales will be controlled by Seiler.

Seiler North America has currently entered into contractual relationship with two United State Air Force Bases, McClellan Air Force Base located in the Sacramento area, California, and Tinker Air Force Base, located in the Oklahoma City area, Oklahoma. These agreements call for Seiler to test five specific industrial waste feedstocks which are generated from both Bases. This relationship is a step - up agreement which requires successful laboratory scale testing, and pilot testing before a commercial system is built. If successful, a commercial vitrification system will be constructed at each Base. The laboratory portion of this agreement has concluded with the establishment of four formulations which will produce commercial grade glass/ceramics out of the five Air Force waste feedstocks. Drums of the waste feedstocks were sent to Switzerland for pilot testing. Pilot testing took place in the weeks of June 3, 1996 and runs to June 12, 1996. Results are currently compiled and will be published in a formal report.

Seiler is also currently under formal negotiations for a centralized recycling system in the Pittsburgh area for handling drummed hazardous waste materials, and in Mexico for providing a vitrification system for two different industrial customers. In each case, Seiler is negotiating with a joint venture partner who is located in the area of operations and is familiar how business is conducted in that particular area. Seiler's ongoing North American policy will be to build relationships through joint

venture partners, and to continue to expand its governmental and industrial clientele. Future considerations for the Seiler system in North America also include exploring the handling of Superfund sites, ammunition manufacturers and dump sites, and low level and mixed radioactive generators. It is Seiler's belief that going into these new areas are a minimum of two years away.

It will be Seiler's prime consideration, however, in the immediate future, to develop and oversee construction and fabrication capabilities of Seiler vitrification system components in North America. Our engineering staff has already begun to develop specifications, bid documents, and bidders for mass producing several components. This will provide all international Seiler customers with competitive component pricing which should help keep costs low while still maintaining quality. It is Seiler North America's fondest hope to promote a professional quality recycling service for all our customers.

# **Analysis of DOWC/DMC**

by Jörg Burmester, DMC Dresdner Management Consult GmbH

In August 1995, Dr. Weser of Seiler Trenn-Schmelz-Betriebs GmbH approached DOWC for our assistance in subjecting the planned greenfield site investment to a thorough examination and preparing an appropriate document for eligibility for a bank loan. After an initial evaluation with regard to the credit-worthiness of the partners involved, the investment volume required and a rough estimate of the profitability of relevant target markets for this new waste management plant, we as DOWC/DMC were convinced that we would be able to draw up a professional and bankable investment feasibility study for this project.

The aim of this document was to produce, after carrying out all necessary detailed and basic analyses, a basis for decision-making aimed in particular at outside investors for the proposed investment plan.

## **Results of the DOWC/DMS with summary findings**

### **Description of the concept**

According to a detailed sector analysis, the Seiler business concept has a clear opportunity-risk profile, with the opportunities clearly outweighing the risk.

The strategic focus on smaller quantities of highly polluted and thus high-cost hazardous waste grades is of advantage.

The partner is an international and complementary team of high quality and with a great deal of experience in the sector.

### **Technical feasibility**

The functional capability of the planned plant has been thoroughly tested by Lahmeyer International and could be classed as unproblematic, including also in respect of the existing 1:3 pilot plant.

In the view of Lahmeyer International, all relevant legal framework conditions are being met.

Technical processes by competitors are merely at a pilot stage and are not comparable with the Seiler process.

The practicability of constructing the plant within a time limit depends on the funding decision and can be set for summer to autumn 1996.

### **Sales and marketing analysis**

In concrete sales discussions with potential customers, a three-fold capacity utilization of the planned installation could be estimated.

A target turnover of more than DM 10 million at each plant can be seen as realistic.

### **Business planning**

On a conservative estimate, the operating result will be approximately DM 2 million in 1998.

Cash flow will be close to DM 4 million in 1998.

All the main profitability, stability and liquidity figures which are relevant for a loan decision at sector comparison are exceeded.

### **Assessment of the market potential in Germany**

The total volume of the waste market in German is officially 265 million tonnes. The market volume relevant for the first Seiler plant in Freiberg/Sachsen (hazardous waste requiring particular monitoring, graded according to Seiler waste classification, in the Saxony area) is approx. 200,000 tonnes.

At a planned capacity for the first Seiler plant of approx. 10,000 tonnes per annum, this corresponds to a market share in the relevant market volume of approximately only 5 % for the first plant.

A regional market entry of this first plant can thus be considered to be without any problems in principle.

Further Seiler installations for the entire German region after the construction and start-up of the first plant can be assessed as desirable and realistic. The total market volume for the Seiler technology in Germany is approx. 168 million tonnes.

If one were to use the same coefficient, i.e. only 1 per cent, as a strategically desired target market segment for the specific Seiler technology, then this would result in a market volume of approx. 1.7 million tonnes per annum.

If this '1 per cent target market segment' could be covered with the new Seiler technology then, according to this first rough theoretical estimate, 170 of these Seiler installations would result, at a plant-specific capacity of approx. 10,000 tonnes per annum.

Thus, transposing this into a preliminary, roughly estimated future volume of approx. 20 to 30 installations in Germany would seem quite realistic given this background.

Moreover, the market-relevant trends with regard to capacities, arisings of hazardous waste and prices can be assessed as overall positive for implementing this new technology in Germany.

## **Swiss development converts hazardous wastes into usable, commercial grade products**

Thanks to a Swiss development, it is possible to convert hazardous wastes into new, usable, commercial grade products. The first industrial plant of Seiler Pollution Control Systems Inc. (SEPC) was presented to the public today in Döttingen/Switzerland.

The Seiler vitrification process treats hazardous wastes in a multi - stage process and converts them into new, reusable materials. The waste materials are mechanically/thermally pretreated, separated at high temperatures and for the most part oxidized. The hazardous substances such as dioxins and furans are destroyed. The end products generated include, on the one hand, heavy metal oxides and neutral salts in concentrated form which can be recycled. On the other hand, a vitreous, hard and non - poisonous substance is produced which serves as raw material for the production of filler sand, rock wool, foam glass or highgrade blasting sand.

Energy consumption for the process is reduced to a minimum by mixing material of low calorific value and material of high calorific value.

### **Pilot plant in operation since 1988**

So far, the operation on a commercial scale of a vitrification system for specific types of hazardous waste has usually failed because furnaces went out of operation after a short time due to the high temperatures required. Seiler Pollution Control Systems Inc. has succeeded in proving the practical viability of its process in a pilot plant, which was put on stream as early as 1988.

As a result of numerous customer - specific tests on the pilot plant, a large number of firm commitments exist from around the world for the construction and operation of Seiler vitrification systems. Seiler SEPC is therefore planning to erect and operate 15 installations within the next two years. Thus, a plant using the Seiler vitrification process is to be installed in Freiberg, Germany, this autumn with the financial support of the Federal Ministry of Economics, the Saxony Ministry of Economics and Dresdner Bank.



## **Commercially viable materials instead of hazardous substances**

From the start Seiler SEPC, which by the way is listed on the US Nasdaq stock exchange, endeavoured to recycle the glass - like material for a useful, and if possible commercial purpose. To achieve this, it secured the collaboration of the respected US scientist, Professor Charles Henry Drummond III, of Ohio State University, Columbus/Ohio, and the Radian Corporation, a subsidiary of Dow Chemical. This team has succeeded in developing a broad range of commercially viable applications.

The material arising during the Seiler vitrification process exhibits special properties which are valuable for further processing. It is exceptionally hard, with very good chemical durability, and thus very resistant to attack by aqueous solutions and atmospheric agents, and exhibits a special crystal structure. Thanks to these characteristics, a great variety of building materials such as wall or floor tiles, pipes, building blocks or bricks, as a grinding and abrasive medium for high - grade glass blasting materials, sandpaper or polishing compounds as well as heat insulation materials for glass wool, foam glass etc. The broad range of possible uses opens up numerous commercially interesting markets to the material. The recycling process is thus completed, with a secure future, ecologically sound and economically viable. New commercially viable products result from formerly noxious substances.

In Western Europe alone, around 30 million tonnes of toxic hazardous waste are generated which have to be stored in disused mines or in landfills. Since international agreements already prohibit the earlier practice of exporting waste which requires special monitoring, existing landfill space will become even scarcer in future. For this reason, a solution to this problem has been sought at an international level for many years.

**No. 9**

**Combustion of Refuse**

**Derived Fuel**

**in**

**Fuelized Bed**

9

*William J. Red*



# **ABSTRACTS**

(as of April 15, 1998)

## **IT3 CONFERENCE**

**INTERNATIONAL CONFERENCE  
ON INCINERATION**

**&**

**THERMAL TREATMENT TECHNOLOGIES**

**MAY 11-15, 1998**

**DoubleTree Hotel  
Salt Lake City, Utah, U.S.A.**

## PETROLEUM CONTAMINATED SOILS BY FLUIDIZED BED DESORBER

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### ABSTRACT

Experimental study was carried out to investigate the effects of operating parameters on the performance of a fluidized bed desorber in thermal treatment of petroleum contaminated soils. Soil of top particle diameter smaller than 0.5mm was mixed with diesel oil to prepare contaminated soils with concentration of diesel oil in soil 10% and 1% on mass basis. Thermogravimetric analysis was made using a Cahn balance® to characterize thermal desorption of contaminated soils. Batch operation of fluidized bed desorber obtained 99.9% desorption efficiency at temperatures of ca. 300°C within 30 minutes. Continuous operation of fluidized bed indicated that the mass ratio of the fluidizing gas to the feeding rate of contaminated soil is less important at higher temperature (over 300°C), if proper fluidization is ensured. The periodic operation of fluidized bed desorber shows possibility to reduce the volume of off-gas significantly.

## INCINERATOR CHLORINE EMISSION CONTROL BY PROPER COMBUSTION AIR MANAGEMENT

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### ABSTRACT

Emissions of free chlorine from hazardous waste incinerators have not received the regulatory attention given to that of other chlorine compounds. Hydrogen chloride, various chlorinated organics, and particularly polychlorinated dibenzodioxins and furans have all been studied with some rigor. Free chlorine has been regulated as a hazardous air pollutant (HAP) but not, within RCRA, as a specific stack emission. The upcoming MACT standard includes a limit which will focus on free chlorine.

That limit can lead to feed constraints, either on chlorine content or even total waste feed. In the specific case highlighted, a HAP-driven chlorine feed limit reduced net incineration capacity. Scrubbing free chlorine is not a simple problem in a gas stream that can approach 15% CO<sub>2</sub>.

This paper will highlight the chlorine emissions of a liquids incinerator, and specific mechanical changes made to reduce these emissions. The Deacon reaction is often cited in the Dioxin literature, and is actually the original chemical reaction used to produce chlorine. It is a key to the emission reductions achieved here. Control of combustion and dilution air, along with temperature, are the proven means to avoid free chlorine formation in incineration byproducts.

## COMBUSTION OF REFUSE DERIVED FUEL IN FLUIDIZED BED

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### ABSTRACT

Power generation from Refuse Derived Fuel (RDF) is an attractive utilization technology of municipal solid waste.

To explain behavior of RDF fired fluidized bed incinerator, the commercial size RDF was continuously burnt in a 30 x 30 cm bubbling type fluidized-bed combustor. It was found that 12 kg/h of RDF feed rate was over feed for this test unit and then CO level was higher than 500 ppm. However, 10 kg/h of RDF was sufficient feed rate and CO level was kept under 150 ppm.

Secondary air injection and changing air supply ratio from the pipe grid were effective for the complete combustion of RDF. It was also found that HCl concentration in flue gas was controlled by the calcium component contained in RDF and its level was decreased with decreasing the combustor temperature.

**No. 10**

**Immobilization**

**of**

**Incinerator Ash**

**in**

**Synroc-Glass**

**Material**

*William J. Red*



# **ABSTRACTS**

(as of April 15, 1998)

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plasma melting plant.

As a result of mutual works conducted together with the firm "NUKEM GmbH" an industrial plant for the ash residue melting by capacity 20 kg/h is designed and under construction now.

## CONDITIONING OF ASH RESIDUE FROM RADWASTE INCINERATORS IN INDUCTION MELTER

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### ABSTRACT

Radioactive ash, arising from radwaste (RAW) incineration, is a dispersed, dusty and easily water-leachable material, hazardous in transporting and non-disposable. The most common methods for ash processing, e.g. cementation or compaction, besides additional material expenses, cause the final product mass and volume increase, without ensuring any sufficient chemical and mechanical durability.

In conditioning the ash by using vitrification, a glass or crystalline material with high chemical stability and mechanical strength can be obtained.

The Radon has developed a method for the ash from incinerators conditioning by using an induction melter.

Some comparatively cheap fluxing materials (not more than 11 wt. % in burden), which allow to conduct the ash melting, were selected.

Series of experiments on a simulated ash processing, including the one marked with  $^{137}\text{Cs}$ , were carried out in the pilot plant for the radwaste vitrification by means of a "cold crucible" induction melter. 300 kg of ash were treated. Parameters of process and off-gases, as well as properties of obtained materials were determined.

The capacity on ash processing 6-10 kg/h at specific expenses of electric power for the vitrification 4-5 kW\*h/kg was achieved. The factor of ash volume reduction was more than two. The density of final product was 2.7 g/cm<sup>3</sup>. The slag discharging was carried out at temperature 1600-1700 °C. The leaching rate of Na<sup>+</sup> from the slag was 3\*10<sup>-6</sup> g/(cm<sup>2</sup>\*day) in a 7 days.

The dust emission from the crucible was hardly dependable on the burden type and was not more than 2 wt. %. Making account to dust returning into the crucible about 99.8% of  $^{137}\text{Cs}$  was included in the melt.

The main unit of gas purifying system for the ash vitrification is a hose filter with the impulse regeneration. The efficiency of purification from aerosols was not less than 97 % (in average 99 %), and the outgoing concentration of dust was not more than 5 mg/m<sup>3</sup>, volumetric radioactivity was not more than 5\*10<sup>-6</sup> Bq/m<sup>3</sup>.

As a result of conducted experiments a project of full-scale melter was developed. Now a unit for the ash vitrification by using "cold crucible" induction melter is under assemblage in a reconstructed RAW combustion plant of Radon.

## SYNTHESIS AND APPLICATION OF THE BINDING MATERIAL BASED ON RADIOACTIVE GROUNDS AND SILTS

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### ABSTRACT

In Moscow SIA RADON the researches on application of a method for processing radioactive silts and grounds, are carried out. The radioactive silt (ground) containing organic impurity natural (peat, natural products of habitability of the animal and vegetative world) and/or artificial (petroleum, polymers) the origins, are mixed with dry-weighed additives, among which the dry residue liquid radioactive wastes can be used also. The received mixture is heated up at 800 to 1000°C. The product is ground to a surface area size of 2500 to 3500 cm<sup>2</sup>/g, mixed with water at a water-to-cement ratio not less than 0.3, and aged to form a solid monolith.

The method will allow to reduce volume of a final product due to combustion of an organic part of a processed material; to increase of the hardening characteristic of a final product due to exclusion from its structure of harmfully influencing organic impurity; to expand range of processed materials containing radioactive organic components up to 80 %mass of both natural, and artificial origin. The method will allow to exclude from technological process a expensive building material - portland cement.

The research of application of a method was conducted with use of actual silts and grounds, polluted by radionuclides.

The results of work shown, that the use of a developed method for processing radioactive silts and grounds allows to receive a cement matrix with good hardening characteristics and, simultaneously to receive volume reduction factor of a final product compared to volume of processed materials, and in some cases - to reduce volume in 2-5 times (at processing silts and grounds with the contents of organic components 40-80 %mass), and also to reduce leaching rate of radionuclides. Also, the results of experimental processing radioactive silts and grounds are given.

## IMMOBILIZATION OF INCINERATOR ASH IN SYNROC-GLASS MATERIAL

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### ABSTRACT

"Synroc-glass" material was obtained from incinerator ash and Synroc additives (CaO, BaO, Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, ZrO<sub>2</sub>) by melting at 1350-1500 °C. Waste oxide content in the waste form reached 30-35 wt.%. Material contained both vitreous and crystalline phases. Crystalline phases zirconolite, hollandite, and rutile were found in a sample poured onto a metal plate. Slow cooling encourages formation of additional phases: celsian BaAl<sub>2</sub>Si<sub>2</sub>O<sub>8</sub>, leucite KAlSi<sub>3</sub>O<sub>8</sub>, and benitoite BaTiSi<sub>3</sub>O<sub>9</sub>. Vitreous phase content ranges between ~10 and ~40 vol.%. Simplified formulations based on incineration ash and TiO<sub>2</sub> were also designed and produced in a resistive furnace and a cold crucible. These materials contained both vitreous phase and few crystalline phases (rutile, pyroxene-type, whitlockite, spinels). Leach rates of Cs radionuclides from the quenched and annealed samples were found to be very similar. Leach rates of  $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$ , and  $^{239}\text{Pu}$  from slowly cooled (annealed) samples measured using seven-day MCC-1 test were found to be ~0.5 g/(m<sup>2</sup> day), 0.03-0.05 g/(m<sup>2</sup> day), and ~10<sup>-4</sup> g/(m<sup>2</sup> day), respectively, being similar to leach rates of radionuclides from conventional Synroc-C.

**No. 11**

**Incineration and Melting**

**of**

**Sewage Sludge**

**by**

**Vortex (Slagging) Furnace**



*William J. Hall*



# **ABSTRACTS**

(as of April 15, 1998)

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## **INCINERATION AND MELTING OF SEWAGE SLUDGE BY VORTEX (SLAGGING) FURNACE**

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### **ABSTRACT**

Sewage sludge incineration and ash melting by the Vortex Melting system is described, based on the operation of two commercial plants. About 90% of inorganic sludge fed into the system was immobilized as slag, and heavy metals were immobilized in the slag with no leaching effects. The slag can be recycled into materials for construction and other effective uses.

The relationship between particle size distribution and incineration was analyzed for developing the most effective method of simulating the Vortex Melter. The sewage sludge was dried and pulverized to the optimum particle size of less than 1.0mm, before being fed into the Melter.

## **INCINERATION OF INDUSTRIAL HAZARDOUS WASTES IN A FBC INCINERATOR: AN EXPERIENCE WITH FLUIDISED BED COMBUSTION TECHNOLOGY**

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Anna university Madras India

### **ABSTRACT**

The destruction of industrial hazardous wastes by thermal oxidation has been an established technique for over decades now, and the process is being continuously sharpened and improved to make it more efficient, eco-friendly and cost-effective. In the globally competitive market place, industry is looking for economic solutions to waste management to protect their bottom lines and viability. While technically, one can use a Rotary Kiln, Multiple Hearth, Multiple Chamber, Fluid Bed Incinerator or any other device to destroy hazardous wastes, the major challenge remains cost effectiveness both in terms of capital investment and the recurrent revenue cost. The economies of scale are also a prime consideration for selection of incinerators. Further, with the escalating cost of energy, it is imperative to look for solutions which consume least external energy. With these objectives, a project was initiated by Sandoz (India) Ltd, Indian affiliate of the multinational Sandoz International, in 1987 which culminated in the use of Fluid Bed Incineration Process as a very strong alternative for destruction of toxic wastes generated by hazardous process industry. The R & D work on use of a classical bubbling type fluid bed for incineration of toxic wastes was presented by the authors at the ASME Conference on Fluid Bed Combustion 1991 in Montreal, Canada. This was followed up by designing, engineering and commissioning a commercial small scale FBC incineration facility in a multi-product hazardous process industry site in Bombay in 1993-94. The objectives were to incinerate a wide variety of real-life wastes emanating from a hazardous process industry manufacturing speciality chemicals, agro-chemicals, bulk drugs and pharmaceuticals and to demonstrate that the FBC technology can be very effectively and efficiently used to design affordable incinerator systems for toxic wastes and achieve a high incineration efficiency and the target Destruction and Removal Efficiency (DRE) to meet the regulatory norms. The paper summarises the experience with this commercial FBC Incinerator over a period of four years with a variety of hazardous wastes of over 800 tonnes generated by industry. The facility has demonstrated its performance and has been welcomed by the State and Federal Pollution Control Authorities as a Demonstration Plant for incineration of hazardous wastes.

## **OXYGEN INJECTION FOR MULTIPLE HEARTH SLUDGE INCINERATORS**

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### **ABSTRACT**

Oxygen-enhanced multiple-hearth sludge incineration was the focus of a five-month joint study by Praxair and the New York State Energy Research and Development Authority. Testing and demonstration were conducted in Rochester, NY, at Monroe County's Frank E. Van Lare Sewage Treatment Plant on an 11-hearth multiple hearth furnace. A simple retrofit of high-momentum oxygen lances created a convection hearth in which convective heat and mass transfer with the drying sludge were greatly enhanced, while hearth temperatures were moderated by the wet sludge. Nominal capacity was 2.2 dry tons per hour (TPH) of sludge, and testing was conducted with one TPH of oxygen. During short-term controlled tests, sludge throughput was increased 55 percent while fuel gas consumption was reduced 35 percent. During long-term operation, throughput was increased over 30 percent while specific fuel consumption was reduced between 10 and 24 percent. Gaseous and particulate emissions per unit of sludge processed were generally reduced with oxygen injection, as were metals emissions. These benefits were gained without adverse effects on the process, the equipment, or the environment. Oxygen enhancement of multiple-hearth sludge incinerators can be economically viable, with a savings between \$30 and \$60 per hour at Van Lare based upon increased sludge throughput and reduced fuel consumption.

**No. 12**

**Properties of Energy Recovery**

**by Combustion**

**of Industrial Waste & Coal Premix Fuels**

*Miller G. Rd*



# **ABSTRACTS**

(as of April 15, 1998)

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## PROPERTIES OF ENERGY RECOVERY BY COMBUSTION OF INDUSTRIAL WASTE AND COAL PREMIX FUELS

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### ABSTRACT

With the call intensifying for globally addressing the earth's environmental problems, demand for increased efficiency in utilizing resources and energy is growing. Waste-related problems, in particular, as they have been addressed with a focus on volume reduction and proper disposal, have raised a new area awaiting research: Can waste be a viable source of energy?

Among a number of types of waste, one that is receiving great interest is industrial waste, which is generated from manufacturing production and is discharged to communities in many diverse forms. The present study has been conducted with a focus on identifying the recovery characteristics of electric and thermal energy from combustion using a cogeneration system and industrial waste as the main fuel.

Conventional methods of power generation from waste have been limited by the degree to which the steam pressure and temperature in the energy recovery boiler can be increased, due to the effects of the corrosive compositions of waste that attack the furnace casing.

In the present study, coal and waste were premixed and incinerated, then evaluated for their combustion characteristics, with the aims of achieving a method that ensures high temperature, high pressure, and sufficiently stable steam recovery. Industrial waste is characterized by its highly diverse mix of many different kinds of waste. Since identifying its combustion characteristics and conducting stable combustion based on the characteristics thus identified are critical in increasing energy recovery efficiency and consequently improving power generation efficiency, a two-furnace construction for the combustion furnace was employed leading to a highly effective solution to the problem found in conventional methods and also leading to the attainment of our objectives. In the present study we have evaluated combustion characteristics which have attained stability through the combustion of premixed industrial waste and coal, while paying special attention to the combustion characteristics of fluidized bed combustion of coal alone, along with evaluating the characteristics of the exhaust gases resulting from combustion. We have then conducted an evaluation to determine heat recovery characteristics and the other conditions required for increasing the 10% power generation efficiency that can be attained in conventional waste power generation systems to a maximum power generation efficiency of 24%, by recovering steam at a higher temperature and a higher pressure (60 atg./460°C). This paper also describes the operating results of an actual system that was run in the light of the findings of the present study and discusses the effects that this system has shown.

As the world increases its awareness of the necessity of building a recycling society, a wide variety of approaches have been set out to deal with waste-related problems. Looking at a series of recent moves toward legislation in response to this trend, including the enforcement of the Recycling Law and the revision of the Waste Disposal Act in Japan, makes us renew our recognition of how serious a social issue current waste-related problems present.

Against this background, the industrial world has been called upon to address such problems, urging individual industries to make efforts in their own ways. In addition to these individual efforts, nurturing a sound and effective waste-disposal and recycling industry are of critical importance, since delay in achieving this may undermine the foundation for growth in the entire industrial world.

In recent years, in the search for compatibility between the environment and energy, using a highly efficient cogeneration power generation proposed as one viable method of recovering and utilizing energy from industrial waste, a source of energy which has yet to be exploited. When it comes to constructing a cogeneration system using waste as fuel, however, two major technological problems have manifested themselves as gross hindrances; they are (1) how can high-temperature corrosion by the attack of HCl and other exhaust gases generated from waste can be prevented, and (2) how can non flammables contained in waste can be dealt with without causing any adverse effects?

Meanwhile, coal, a solid fuel, is inferior in physical and chemical properties as a fuel compared to petroleum. With the aim of expanding demand for coal, studies are being conducted widely on fluidized bed combustion technology, which is a combustion technology that may make coal a stable and homogeneous fuel.

In the present study, coal and waste have been premixed and incinerated, then evaluated for their combustion characteristics, while paying special attention to the combustion characteristics of coal alone in fluidized bed combustion, with the aim of achieving a method that ensures high temperature, high pressure, and sufficiently stable steam recovery. The present study has also analyzed the results of this evaluation in order to identify the conditions required for stable combustion and obtain knowledge of heat recovery characteristics and other matters.

This paper also describes the operating results of an actual system that was run in the light of the findings of the present study and discusses the effects that this system has shown.

## MODEL PREDICTIVE CONTROL AND ON-LINE OPTIMIZATION OF A SELECTIVE CATALYTIC REACTOR FOR NO<sub>x</sub> REMOVAL IN INCINERATION PLANTS

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### ABSTRACT

This paper presents the results regarding the application of a simulation tool as supervisory system for NO<sub>x</sub> removal in a municipal waste incineration plant.

The optimization procedure consists of the search of the best working conditions that satisfy the operating and legal constraints, in terms of emission amounts and combustion quality. This procedure adopts a simulation algorithm and data reconciliation tool to verify and improve the consistency of the calculated values by experimental data.

In order to optimize the DeNO<sub>x</sub> section performance, a reliable simulation model must include a detailed description of each plant section and the formation/reduction kinetics of different pollutants throughout the different units.

**No. 20b**

**MWC Ash Recycling:**

**A Commercial Reality**

## MWC Ash Recycling: A Commercial Reality

*Presented by:*

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American Ash Recycling (AAR) is a wholly-owned subsidiary of Environmental Capital Holdings, Inc. ECH, through its subsidiaries, specializes in the processing and recovery of recyclable materials with the specific focus on Municipal Solid Waste Combustor (MSWC) ash and in construction demolition debris. ECH's engineering subsidiary, Duos Engineering B.V., located in the Netherlands and in the U.S., is well established in Europe as a leader in recycling technologies.

AAR is effectively addressing the challenge of MSWC ash disposal. Through AAR's unique approach, the ferrous and non-ferrous metals are recycled and the aggregate manufactured is sold for commercial reuse. Drawing from an international management team with extensive experience in the design, construction, and operation of MSWC ash processing systems, AAR has developed the most comprehensive solution available to the problems of ash disposal. The AAR system effectively deals with all aspects of proper management and processing of MSWC ash.

This dramatic forward leap in the realization of commercial ash reuse in the United States is due in part to the heritage supplied to AAR by one of ECH's European subsidiaries, Duos Engineering, B.V. Duos' experience includes an eight year history in the design, project management, construction and start-up of recycling systems for MWC ash in all of its three forms: bottom ash, fly ash, and combined ash. Duos has developed two proprietary air separation technologies, which are particularly important in an ash recycling application. These are the Windzifter® unit and the Stijgzifter® unit.

These units are utilized in bottom ash recycling for removal of unburned paper, plastics, wood and other impurities. MSW Combustor ash recycling facilities in Holland designed by Duos recover both ferrous and non-ferrous metals, remove unburned material, and prepare the remaining ash for uses such as roadbed material or as a substitute aggregate in asphalt.

In The Netherlands, there are 8 MSW combustors operating and 3 are under construction, which consume 4.3 million tons/year of MSW and generate 1.1 million tons/year of ash. Duos has been involved in the design and construction of six MSW

The Nashville plant is a year-round operation completely enclosed in a steel building. It features an elevated control room which contains the Motor Control Center and the computer management system. The plant is operated and monitored by software designed and developed by AAR. As to the overall process flow, the single input stream of combined ash yields six streams out: aggregate, three sizes of cleaned ferrous, cleaned non-ferrous, and unburned combustibles. The process itself is a careful combination of physical screening, aggregate sizing, metals recovery, metals cleaning, unburned removal, and chemical treatment of the aggregate.

At the Nashville operation, combined ash is mined by AAR from Metro's monofill. Typical feed rate into the plant is 100 tons/hour. This material is first conveyed to initial screening, which separates the combined ash input into multiple size gradations for further processing.

The largest element from initial screening next passes magnetic separation which extracts the coarse ferrous metals and deposits them in the ferrous cleaning unit. The remaining unburned coarse material is then conveyed to a roll-off container for return to the incinerator. The medium fraction from initial screening also undergoes magnetic separation with the recovered metals directed to the ferrous cleaning unit.

The remaining materials are conveyed to the downsizing unit, where they are joined by the return loop from the Windzifter® (to be described later). The output from the downsizing unit is then combined with the materials from other screening units, and this combined stream again passes magnetic separation. Any ferrous metals extracted at this point are conveyed to the ferrous cleaning unit.

At this point in the process, virtually all of the ferrous metals have been removed from the ash stream and have been moved to the ferrous cleaning system. Metals cleaning is a unique feature of the AAR process and a major improvement over the first generation facility in Sumner County. This process of cleaning and sizing not only enhances the economic value of these commodities, but it also eliminates any concerns about ash migration with metals being shipped to the scrap yards and mills.

The combined output from the downsizing unit and other sized streams flow to the aggregate separation unit. This unique apparatus separates the final aggregate product, which is less than 3/8 of an inch in size. Typical aggregate flow from the aggregate separation unit is in the 80 tons/hour range, while roughly 50 tons/hour of oversized materials from the aggregate separation unit goes next to the non-ferrous separator. Aluminum, brass, copper, and coins removed by this unit are then conveyed to the non-ferrous cleaning system.

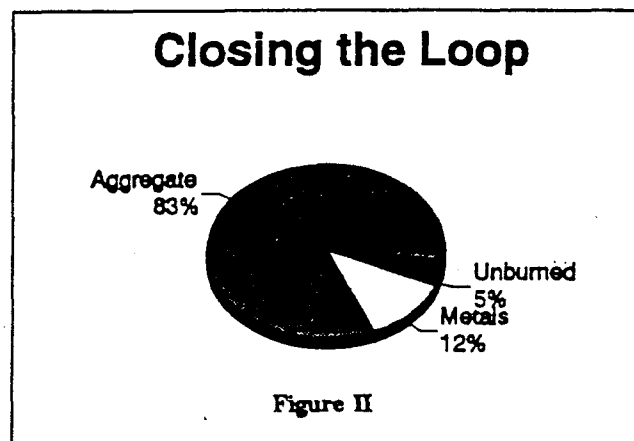
The non-metallic materials which pass the Non-Ferrous Separator are directed to the Windzifter-, which utilizes multiple air separation technologies to remove the unburned combustibles such as paper, plastic, wood and other contaminants from the ash stream. These contaminants are then discharged through air locks and conveyed to the same container which also receives the coarse



cadmium (see Figure I), these have always been significantly below the regulatory threshold.

Air discharges at AAR's Tennessee facility are below the very stringent limitations in the air permit of less than 0.62 pound per hour from all sources. These standards were established by AAR-directed computer modeling in cooperation with Metro's Department of Health. On the water side, AAR's process allows for **zero** discharge. All of the plant water is processed through a proprietary slurry system and recycled.

Through February of 1994, AAR's Nashville plant had produced 29,700 tons of aggregate and sold 24,685 tons of aggregate to applications including asphalt manufacture, roadbed, structural fill, and pipe bedding. AAR recently entered into an agreement with a concrete products company for the production of curb stops, patio steps, and similar products made with AAR aggregate.



Examining Figure II, entitled "Closing The Loop", it is somewhat dramatic to note that there is virtually no waste stream from an AAR ash recycling facility. Over **80%** of Nashville's ash is converted into a valuable construction aggregate, approximately **13%** of the ash is recovered as high-grade metals, and roughly **5%** of the ash is separated as unburned material and returned to the incinerator. For those of us who accept the premise that thermal recovery is a form of recycling, the Nashville operation truly, and for the first time in America, represents 100% recycling!

In summary, AAR employs an ash processing and utilization system which has now been proven in the United States in addition to the years of experience accumulated in Europe, in many cases rendering ash monofills obsolete. AAR's demonstrated success in monofill mining creates new opportunities for reclaiming existing monofills. As a specific example, Nashville's ash monofill has historically grown by 12,000 to 18,000 cubic yards per quarter. In the

**No. 23**

**Shopping For Alternative**

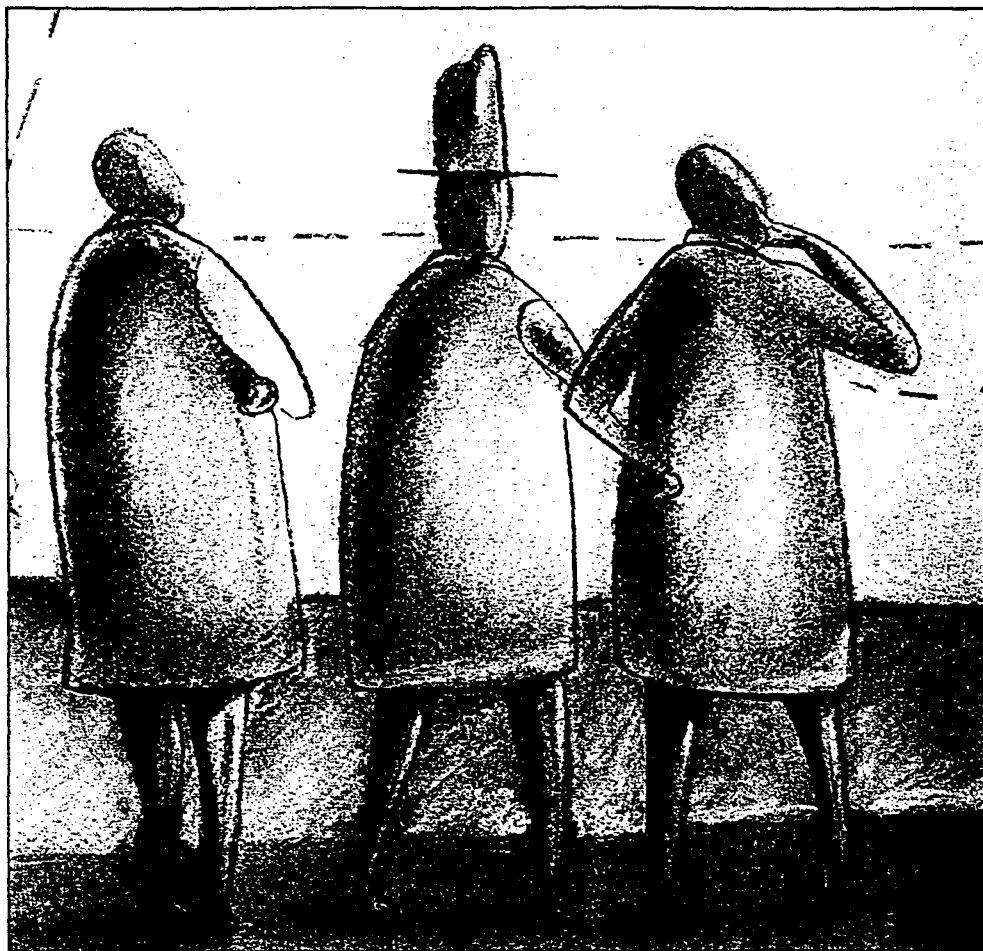
**Daily Covers**

**No. 24**

**Shopping For Alternative**

**Daily Covers**

"One  
man's  
trash is  
another  
man's  
treasure."



# SHOP

## For Alternative

*A Comparison of the Four Main Types of ADCs*

**T**he single most valuable asset of a landfill is the airspace available for waste disposal. Efficient use of this asset can therefore translate directly into increased profitability, lower operating costs, and longer service life of a landfill. The application of a soil daily cover, typically 6 inches thick, can account for 5% to 33% (or more) of a landfill's design capacity, depending on cover thickness, waste filling rates, and operational practices. Accordingly, daily soil cover can result in a significant loss in revenue. As a result, alternative daily covers (ADCs) are becoming increasingly popular for use in landfill applications.

Several types of ADCs are available commercially: (1) reusable tarps, (2) thermally degradable membranes, (3) spray-applied slurries, and (4) spray-applied foams.

# OPPING Daily Covers?

**By James W. Isensee and Peter D. Creamer**

*Editor's Note: This article was adapted from a paper presented at Waste Tech '98, held in February in San Antonio, Texas.*

### ***Devil's in the details—and the dirt***

As in much of the rest of life, in landfill construction and operation, the devil is in the details. Dirt is a big detail in landfills, and historically, the greatest requirement for dirt at landfills of significant size has been daily cover. In areas where landfill excavations are relatively shallow, dirt availability becomes a concern early in a landfill's operational life. For deeper landfills, the issue does not often become a concern until closure approaches.

Subtitle D requires that waste must be covered at the end of each operating day, or more frequently if necessary, with at least 6 inches of earthen material to control disease vectors, fires, odors, blowing litter, and scavenging. For nonhazardous industrial waste landfills, the individual states typically have regulations with similar requirements.

The requirement for daily soil cover leaves landfill operators with the option of scraping off the daily cover at the beginning of every workday for reuse (if allowed by the regulatory authority) or losing significant airspace over the life of the site. Scraping off the soil will not be 100% efficient, and it will significantly increase the time required to deal with daily cover. Assuming a range in average daily waste thicknesses between 1 and 10 feet, if the daily cover soil is not removed, then a minimum reduction in a landfill's waste capacity of between 5% and 33% will result. This represents a reduction of similar magnitude in tipping fee revenue at a landfill.

However, a subsection of Subtitle D allows the use of alternative materials of different thicknesses to accomplish the same objectives listed for soil cover as long as they do not present a threat to human health and the environment. Other Subtitle D requirements for liners, leachate collection systems, interim and final covers, financial assurance, etc., generally have increased the square-foot cost of landfills. With the waste collection and disposal market being so competitive, the push is on to cut costs and increase efficiency wherever possible.

In areas such as the northeastern U.S., where stringent landfill regulations were in effect prior to Subtitle D, landfill operators have been experimenting with ADCs for some time. Since the implementation of Subtitle D, this trend has spread nationwide.

Landfill operators are discovering that the costs of excavating, hauling, and placing daily soil cover can significantly exceed the cost of purchasing and installing

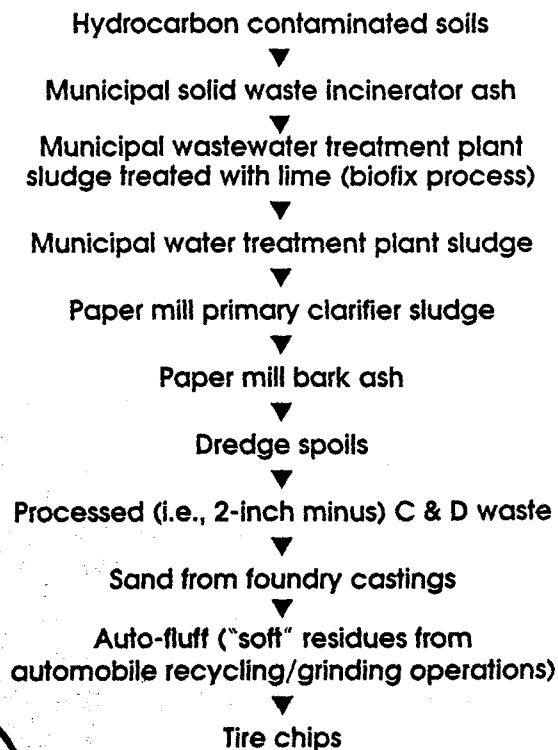
some ADCs. Add the moderate to significant cost benefit of potentially increasing landfill waste capacity by 5% to 33% and the revenue generating advantage of using an ADC becomes evident rather quickly. Fortunately for landfill operators and owners, competition between manufacturers and suppliers of ADCs has increased; thus, the cost of using ADCs is decreasing.

### ***Reusable tarps***

Reusable tarps are essentially blankets that are spread out over the waste and then retracted as required by landfill operations. There are a variety of commercially available reusable tarps on the market that are used as ADCs. The most common tarps used for ADC are constructed

## **Waste Product ADCs**

The saying "one man's trash is another man's treasure" is an apt description of a landfill operator using a waste material as an ADC. The most cost-effective ADC is a waste material that, under a best-case scenario, a landfill is paid to accept. State regulators have approved a variety of waste ADCs for use at municipal and/or non-hazardous waste landfills. They include:



*Isensee and Creamer are senior project engineers with RMT, Inc., in the company's Austin, Texas, and Madison, Wis., offices, respectively.*

with a low-density polyethylene coating, top and bottom. TEL also manufactures, from base materials, Durashield 11000 FR, which is a woven polypropylene fabric with a polypropylene coating.

Several standard tarp sizes are typically available from each manufacturer. Sizes typically start at approximately 50 feet by 50 feet and go up to approximately 100 feet by 100 feet. Larger custom tarps are made by sewing together the smaller standard sizes. The AirSpace Saver, for instance, comes in a standard 48-foot-by-50-foot size. Panels of this standard size are regularly sewn together to make tarps up to 48 feet wide by 333 feet long (16,000 ft<sup>2</sup>) for use with a Tarpomatic, a specialty piece of equipment that attaches to a bulldozer or compactor and can quickly deploy and retract large tarps.

All of the above tarps can be used repeatedly (deployed and retracted) for daily cover or can be left stationary for long periods of time as interim cover. Depending on the size of the area being covered and the manpower available at the landfill, they may be deployed and retracted by hand or by using standard landfill equipment or specialty equipment such as the Tarpomatic.

Tarps have a proven track record at many landfills of being an effective ADC that will generally control dust, litter, vectors, and rodents. Uncoated geotextile tarps have varying degrees of permeability to vapors and water. They will accordingly control odors to varying degrees while the waste is covered. Trapped odors will be released, however, when the tarp is removed whether the tarp is permeable or nonpermeable.

Where leachate and/or biogas production is of concern, the permeability of the noncoated geotextile tarps can be reduced by using a tarp that is constructed of a heavier weight fabric (heavier weight fabrics usually have lower permeability rates than lighter weight fabrics) or by compacting the waste to form a smooth and sloped working face. Alternatively, a coated geotextile or film-based tarp can be used.

The life of a tarp is affected by the way in which it is handled and the size of the tarp. Handling the tarps by hand maximizes their useful life. Hand placement of the tarps has the drawback, however, of placing landfill personnel in the position of walking directly on top of the waste, which is a safety concern.

Compared to handling by hand, deployment and retrieval of the tarps with landfill equipment, such as compactors or bulldozers, will reduce the useful life of the tarp by approximately one third to one half. This is due to the fact that a tarp is usually handled rougher when heavy equipment is being used than if only manpower is

employed. A smaller tarp will also generally last longer than a larger tarp since larger tarps are typically subject to higher forces while being deployed and retrieved.

On average, reenforced tarps have a useful life of between approximately six months and three years when used as ADC on municipal landfills.

Because tarps have a defined geometry and on-site quantities may be limited, soil cover may still be needed to completely cover the area requiring daily cover. Tarps have also been reported to be difficult to handle in high winds or if they get wet or muddy unless specialty equipment is used. Some landfill operators in northern climates shy away from tarps because of the difficulties of heavy snowfall and freezing water, which can make tarps difficult to retrieve.

It is widely acknowledged that reusable tarps, in terms of material costs, are the most economical type of ADC. This is due principally to the fact that the tarps are reused while other alternative cover materials are used a single time. Even if the economic benefits of saving landfill airspace were not considered, the cost of using tarps is generally still less than the cost of using soil as daily cover.

### *Thermally degradable membranes*

Thermally degradable membranes (TDMs) consist of a polyethylene film that is designed to be used once and then left in place. The plastic film thermally degrades into nontoxic components within the landfill and is then tear- and puncture-resistant with a rated elongation of 500%. The useful in-place life of the standard versions of TDM is approximately four to six weeks.



**A thermally degradable membrane** is deployed using a bulldozer-mounted landfill rover.

## Alternative daily covers contd.

The standard thickness of most TDMs is 2 mil.

Two manufacturers produce TDMs: EPI Environmental Products, Inc. (Conroe, Texas), and In-Line Plastics, Inc. (ILP, Houston).

Each manufacturer supplies its TDM in standard 16-foot-wide rolls containing approximately 5,200 linear feet of film (2-mil thickness). They are applied in consecutive strips with a recommended 6-inch overlap using a hydraulically controlled roller and soil hopper/dispenser that attaches to a bulldozer or compactor.

The applicator equipment simultaneously deploys the TDM and soil on top of the TDM for anchorage. A second person is sometimes used to cut the role of TDM at the end of each pass across the face of the waste. An ILP representative also stated that, for sites with a daily working face of 1,000 ft<sup>2</sup> or less, the TDM can be applied as quickly by hand as with the equipment. This method of deployment, however, presents similar safety concerns as the deployment of tarps by hand.

Some of the criticisms about TDMs from various

landfill operators were that the trash could be dragged onto clean areas, the TDM could ball up in winds because the ballast might not always be evenly distributed, and the TDM can puncture if the waste is not well compacted.

TDM can be cheaper to use than dirt even if the airspace savings were not considered. Like tarps, TDMs have a proven track record at many landfills of being an effective ADC that will control dust, litter, and vectors. TDMs also control odors and can prevent the infiltration of water into the waste if the waste surface is relatively smooth and adequately sloped.

The TDM manufacturers state that it can be placed in winds up to 40 to 50 miles per hour, but must be applied in the direction of the wind if the wind is very strong. It is only adversely affected by wet conditions to the extent that the bulldozer operating the application equipment is affected. Application of TDM actually works better when it is raining in the sense that the added weight of the water on the TDM helps to hold the

## Pros & Cons

Type of ADC	Advantages	Disadvantages
<b>Reusable Tarps</b>	<ul style="list-style-type: none"> <li>■ Economical</li> <li>■ Tarp and applicators simple to use</li> <li>■ Reusable</li> <li>■ Low time requirements</li> <li>■ Coated types impermeable if maintained</li> </ul>	<ul style="list-style-type: none"> <li>■ Coverage area limited by tarp geometry</li> <li>■ Workers may have to walk on waste to deploy or retrieve tarp</li> <li>■ Specialty equipment may be costly</li> <li>■ Odors, snow, mud, wind, and freezing water potential problems</li> </ul>
<b>Thermally Degradable Membranes</b>	<ul style="list-style-type: none"> <li>■ No limitations to cover area size and shape</li> <li>■ Simple to use</li> <li>■ Applicator equipment simple and not too costly</li> <li>■ Low time requirements</li> </ul>	<ul style="list-style-type: none"> <li>■ Some limitations to types of soil used for ballast</li> <li>■ Dry ballast required for freezing conditions</li> </ul>
<b>Slurries</b>	<ul style="list-style-type: none"> <li>■ No limitations to cover area size and shape</li> <li>■ Simple to use</li> <li>■ Low time requirements</li> <li>■ Applicator equipment may have other uses</li> </ul>	<ul style="list-style-type: none"> <li>■ Must purchase or lease applicator equipment</li> <li>■ Vulnerable to rain during curing</li> <li>■ Material costs relatively high</li> </ul>
<b>Foam</b>	<ul style="list-style-type: none"> <li>■ No limitations to cover area size and shape</li> <li>■ Variety of applicator equipment available</li> <li>■ May be applied in rain prior to curing (Sanifoam)</li> <li>■ Low permeability (Sanifoam)</li> <li>■ Suitable for balefills (Rusmar)</li> </ul>	<ul style="list-style-type: none"> <li>■ May need to purchase or lease applicator equipment</li> <li>■ Up to two times amount of material may be needed for application in hard rain (Sanifoam)</li> <li>■ Material costs relatively high</li> <li>■ Erodes in heavy rain (Rusmar)</li> </ul>



## Alternative daily covers contd.

film down.

Besides the advantage of having to handle a TDM only once daily, compared to twice daily for a tarp, the specialty equipment may be considered easier to use than the Tarpomatic. This is because the TDM applicator equipment is less cumbersome to use due to its smaller size.

An additional advantage of TDMs over tarps is that, as long as enough product is available on-site, a TDM can completely cover the area requiring daily cover regardless of its geometry.

TDMs are available in 2-mil, 3-mil, and 5-mil thicknesses. Given the same formulation, a thicker film will degrade slightly slower than a thinner film. The typical reason a thicker film is sometimes specified, however, is not because of degradation, but because it is stronger and more resistant to puncture than a thinner film.

The material cost of TDMs and other ADCs compared with reusable tarps is a function of the thickness of the daily waste lift thickness and the life of the tarp. TDMs become more cost competitive the thicker the waste lift. Another consideration that may make TDMs an attractive ADC is the lower man-hour requirements to handle the material and the ability to cover nonrectangular and larger-than-expected areas.

The competitive nature of the marketplace also appears to be driving the manufacturers of TDMs to provide the applicator equipment to larger-sized landfills at a nominal cost above the square-foot cost of the TDM. Both TDM manufacturers offer a variety of acquisition, lease, and free-use programs for landfills for both sampling and long-term use of their applicators.

### ***Spray-applied slurries***

Spray-applied slurries (SASs) consist of solids that are mixed with liquid and spray-applied to the waste surface. They are typically made of recycled materials that form a slurry when mixed with water.

Several commercial SASs are on the market that function as an effective ADC. Four commonly used SASs are ConCover and ProGuard, manufactured by New Waste Concepts (Perryburg, Ohio); Topcoat, manufactured by Central Fiber Corp. (Wellsville, Kan.); and Posi-Shell, manufactured by Landfill Service Corp. (Appalachian, New York).

ConCover is a recycled newspaper, wood fiber, and polymer-based slurry; and ProGuard is made from recycled cellulose (mixed papers) and a proprietary bonding agent. Topcoat is made of recycled newspaper and magazines and a proprietary binding agent. Posi-Shell is a bind-



A cement-based slurry is applied to waste.

ing agent (cement, kiln dust, fly ash, etc.), plastic fiber, and cellulose-based slurry.

The slurries dry to form a thin crust on top of the waste. ConCover, ProGuard, and Topcoat cure within 30 minutes to an hour, and Posi-Shell sets up between 20 minutes and two hours. They can all be applied in a light to moderate rain and still cure to form an effective cover.

Slurries are applied using a spray applicator that is capable of spraying the slurry a distance of 150 to 200 feet. The applicators are typically trailer-mounted commercial hydro-seeders that are pulled by a bulldozer. At least one landfill operator, though, has mounted the spray applicator on a 6-by-6 army surplus truck to minimize travel time. A drawback, though, of this type of setup is that if the truck breaks down, the applicator is then also out of commission.

For ConCover, ProGuard, and Topcoat, spraying of the slurry over the face of the waste is recommended to be done from at least two directions to ensure proper coverage. Posi-Shell can be sprayed from a single direction and will provide adequate coverage. For smaller working face areas that can be reached from one or two locations, a single operator can efficiently cover the waste. For larger working faces, two operators are usually used.

Like TDMs, slurries are more cost-effective the thicker the daily waste lift. Generally, slurries are cheaper to use than dirt if the airspace savings were considered.

At a 3,100-tpd landfill near Salt Lake City that is a soil-deficient site due to high groundwater, half of the working face (approximately 10,000 ft<sup>2</sup>) is covered with Posi-Shell, and the other half is covered with at least 6 inches of auto-fluff, the "soft" residues from automobile recycling/shredding operations. The auto-fluff is a waste

## Alternative daily covers contd.

that the landfill is paid to take so it is less expensive to use than a commercial ADC. The landfill operator stated he was pleased with both of the ADCs and that auto-fluff was only used on half the working face due to supply limitations. The auto-fluff is somewhat dusty, however, which resulted in occasional equipment problems such as clogged air filters and radiators. The Posi-Shell was cheaper to use than dirt (without considering the airspace savings) since soil had to be imported from off-site.

Similar to tarps and TDMs, slurries have a proven track record at many landfills of being an effective ADC that controls dust, litter, and vectors. Slurries generally provide good odor control. ConCover, ProGuard, and Posi-Shell are also considered to prevent the infiltration of water into the waste. Topcoat will absorb a certain amount of water and, once it reaches its absorption capacity, will begin to shed water. (It is presumed at the same time to also begin percolating water into the waste.)

Similar to the TDMs, effective shedding of water may be difficult with any of the slurries if the surface of the waste is not adequately sloped and/or relatively rough and pockmarked with small depressions that will hold water.

Advantages of slurries include the use of recycled materials; the ability to cover nonrectangular and larger-than-expected areas; the ability of the spray equipment to be used for revegetation work, dust control, fire-fighting, and power washing; and the fact that leachate may be used for the mixing and spray water.

The disadvantages of slurries are that equipment must be purchased or leased, and the slurries cannot be applied in heavy rains (greater than 1 inch per hour). Also, Posi-Shell has a relatively low pot life, so it is necessary to use all the material mixed at a given time within a couple of hours after mixing is completed. This can increase costs if an operator overestimates the amount of material needed to cover the working face.

## **ADC Manufacturers**

### **TARPS**

**AMCON Environmental**  
Somerset, Ky.  
606/679-7929 (Tel)  
606/678-6580 (Fax)

**Wire Rope Specialists**  
Baton Rouge, La.  
504/752-1990 (Tel)  
504/755-3448 (Fax)

**National Seal Co.**  
Aurora, Ill.  
800/323-3820 (Tel)  
708/898-3461 (Fax)

**Thor Enterprises, Ltd.**  
Austin, Texas  
800/223-8467 (Tel)  
800/223-8407 (Fax)

**Tarpomatic, Inc.**  
Canton, Ohio  
800/500-5069 (Tel)  
330/484-2021 (Fax)

**Texas Steel Culvert Co., Inc.**  
Arlington, Texas  
817/265-2255 (Tel)  
817/265-2250 (Fax)

**THERMALLY DEGRADABLE  
MEMBRANES**  
**Environmental Products, Inc.**  
Conroe, Texas  
409/788-2998 (Tel)  
409/788-2868 (Fax)

**In-Line Plastics, Inc.**  
Houston, Texas  
800/364-7688 (Tel)  
800/449-5090 (Fax)

**SPRAY-APPLIED SLURRIES**  
**New Waste Concepts**  
Perryburg, Ohio  
800/359-2783 (Tel)  
313/847-9008 (Fax)

**Aqua-Shed Technologies, Inc.**  
Florence, S.C.  
800/661-6646 (Tel)  
800/661-7444 (Fax)

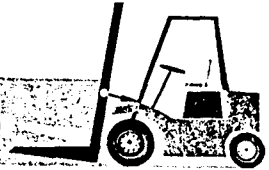
**Central Fiber Corp.**  
Wellsville, Kan.  
800/654-6117 (Tel)  
785/883-4429 (Fax)

**Landfill Service Corp.**  
Appalachian, N.Y.  
800/800-7671 (Tel)  
607/625-2689 (Fax)

**Enviro Group, Inc.**  
Indianapolis, IN  
317/353-8910 (Tel)

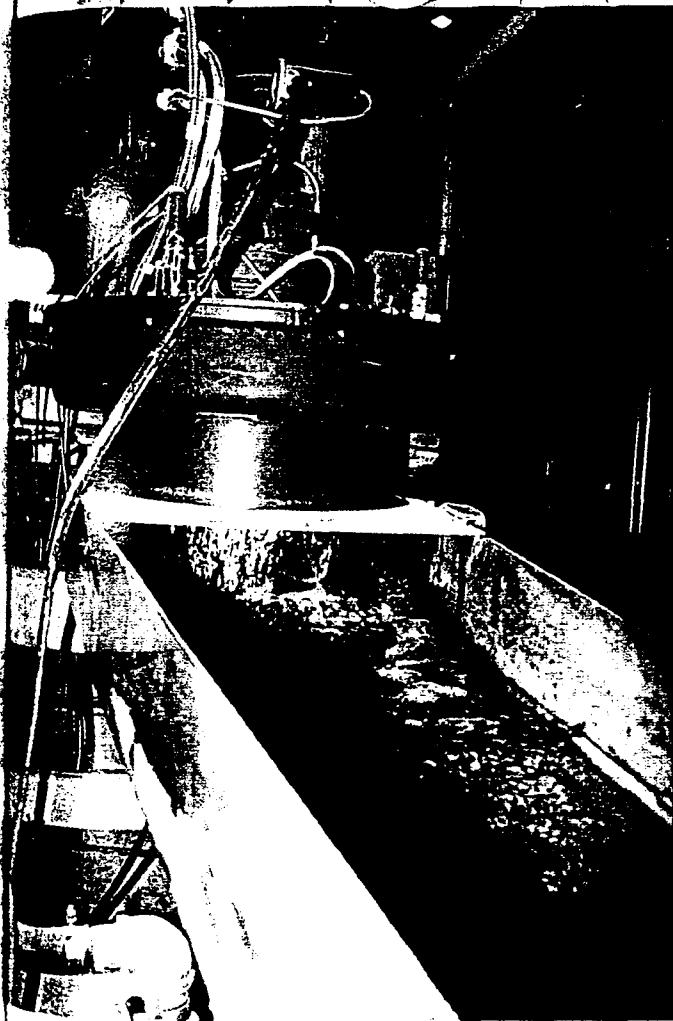
**SPRAY-APPLIED FOAMS**  
**Cover-Foam Services, Inc.**  
Florence, S.C.  
800/617-6297 (Tel)  
803/665-8706 (Fax)

**Rusmar, Inc.**  
West Chester, Pa.  
800/733-3626 (Tel)  
610/436-8436 (Fax)



In the heart of the 'frozen tundra' of Green Bay, Wis., this plastics recycler has made big gains in a low-margin area of recycling.

# *processing plastics in* **PACKERLAND**



## **Fast Facts: Catenation, Inc.**

Location: Green Bay, Wis.  
Square Feet: 50,000

President: Randy Tess

Feedstock: 100% post-consumer plastic containers

HDPE washline installed: 1993

PET washline installed: 1998

Sorting systems handle: colored or natural HDPE; HDPE mixed bales; PET and HDPE; 1-through-7 mix; and mixed PET.

**T**itle Town, U.S.A., home to the Green Bay Packers, "cheeseheads," and paper mills galore, is also the home of Catenation, Inc., a privately held recycling company dedicated to the recovery of post-consumer plastic containers.

Breaking ground in the land of Lombardi, a place football fans endearingly call the "frozen tundra," might not sound easy, but once Catenation opened its doors in 1993, it grew so quickly that its expansion came three years ahead of schedule. In January, the company moved shop, staying close to the original building in Green Bay, Wis., but tripling its size to 50,000 square feet and installing its first polyethylene terephthalate (PET) plastic washline.

**By Heidi Ridgley**

*Ridgley is reporter/markets analyst for  
Waste Age's Recycling Times*

## Catenation, Inc. cont'd.

Catenation's decision to delve into the world of PET comes after successfully processing and then marketing natural and pigmented high-density polyethylene (HDPE) resins to a variety of extrusion, injection, and blow-molding operations across the U.S. and Canada.

"Our plan was to develop a system for HDPE, do it correctly and then back into PET pelletizing," says Randy Tess, the company's president. But what makes the company stand out from the pack is its ability to separate and sort material from a commingled bale. "We cut our teeth on the segregation of mixed bales of plastic," Tess says. "It's our claim to fame."

It also may give the company a competitive edge. "Regardless of the bale composition, we can process it," Tess says.

Catenation's success stems from its ability to consistently produce high-quality resin at a competitive price. "My job is to take feedstock from community collection and make my customers thrilled to get it over and over again," Tess says.

To fulfill his obligation, clean sorts are an absolute must. Tess says he developed Catenation's sorting system because he had a hard time relying on the sorting capabilities of other MRFs. "If they had a bad sorting day, the

potential for contamination here was too great a risk," Tess says. Now, his tactic is to convince MRFs not to waste time sorting plastic. They know paper is their big ticket item, anyway, he says, and plastics are always only an afterthought. "I tell the MRFs, concentrate on sorting the higher grades of paper and I'll do the plastic for you."

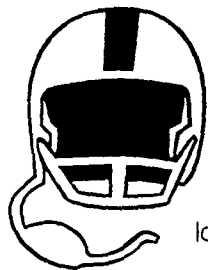
### Scanning & sorting

Catenation uses custom-made, high-speed, computer-driven vision equipment to scan and sort every bottle by category. The computer even can be programmed to distinguish soiled jugs from clean, a selling point for buyers of resin who are insistent on receiving high-grade material.

"Some companies that buy feedstock from us don't want resin from jugs that may be greasy from hitting the side of the baler," Tess says. In this case, the computer is told what percentage of the containers must be free of dirt, grease, or labels.

Sorting containers, done manually during the first two years of operation, used to take 15 workers. "With people, our accuracy was unbelievably poor," he says. "It killed us economically." Now the company employs 50 people, but it is also 20 times larger—with a capacity to

## Packers—not just a football team



Catenation's success comes from its ability to capitalize on its location. Although President Randy Tess's inspiration for the business came while living in Milwaukee, he quickly realized that Green Bay, with its abundant paper mills and packing companies, was the trucking hub of Wisconsin. With attractive backhauling rates—toilet paper out, plastic

bottles in—Catenation belonged in Green Bay. The company receives material from materials recovery facilities (MRFs) all around Wisconsin and the country, with a semi-trailer load coming in each week from the local MRF in Brown County, Wis.

The location also ensured Catenation's steering committee would be peppered with directors seasoned with experience from the paper recycling industry. "The

technology between plastic and paper recycling is different, but the economics are similar," Tess says. "They've already gone through the learning curve for paper recycling. They've seen things plastics recycling hasn't seen yet, but through their synergies, we've been able to glean what they've learned and bring it into the plastics world." ■

—HR

process in excess of 70 million pounds of plastic a year—and runs 24 hours a day, seven days a week.

Few employees, if any, ever actually touch the bottles during the sorting process anymore. But back in the early days—just a few short years ago—hand-sorts involved only commingled bales of natural and colored HDPE, which were processed into pellets. The company began automating once it started sorting mixed PET and HDPE bales, selling the PET unwashed. To end the contamination problems posed by polyvinyl chloride (PVC), which looks similar to PET, Tess installed several PVC detection systems made by Magnetic Separation Systems (Nashville, Tenn.).

From there, the company expanded its capabilities to a plastics Nos. 1 through 7 sort. Catenation now has a separate sorting system dedicated to five different categories: colored or natural HDPE bales; HDPE mixed bales; PET and HDPE; 1-through-7 mix; and mixed PET.

Despite such intensive sorts, little plastic gets landfilled, Tess says. Generally, even the harder-to-market plastic grades, such as those found in yogurt containers, find a home. PVC—currently his only problem—is discarded. Tess says that in a bale of plastic containing Nos. 1 through 7, he hates to see more than 8% of it contain plastics other than HDPE or PET, though he admits he sometimes sees up to 15%. And although his system is able to handle bales containing only 3-through-7s, Tess is not overly excited about processing it. "I'm not jumping up and down saying 'send it to me,' but when it comes, I can find a home for it," he says.

### *Deer legs and debaling*

The whole process from sort to pellet begins when forklifts made by Clark (Houston) and Toyota (Torrance, Calif.) dump bales up to 1,000 pounds into the debaler. Trommels turn through the plastic, sorting out glass, caps, aluminum, and steel, which drop to the conveyor belt and get taken to the landfill. Tess says each bale is different, but on the whole the industry must dispose of about 1% to 4% of non-plastic material shipped from materials recovery facilities (MRFs).

Aside from the usual bottle caps, aluminum cans, and paper contaminants, Tess and his workers have encountered live ammunition, dead pets, and deer legs during hunting season. "You see the strangest stuff in bales," Tess says. "So you better be set up for it and be flexible."

From there, the plastics are sorted by category, granulated, and washed. Then, the material is dried and pelletized. Catenation also blends the flaked material to ensure a consistent density and eliminate dramatic shifts



After granulation, plastics move through the materials cyclone and into boxes for shipment.

in color. The company prides itself on its ability to provide end users with 40,000-pound loads containing the same appearance and properties from front to back.

### *The 'missing link'*

Catenation sprang up after the Wisconsin legislature decided to implement a law requiring the recycling of all plastics grades 1 through 7 by 1995. Most municipalities launched into recycling PET and HDPE grades right away. "There was a lot of publicity about recycling following Earth Day [in 1990] and the [Wisconsin] Department of Natural Resources demanded that HDPE and PET not be landfilled," Tess says.

But before long mountains of the material began to pile up. Tess says. Manufacturers of plastic products wanted only clean, high-quality resin and preferred virgin or post-industrial scrap. "They viewed post-consumer material as a bad idea," Tess says.

Catenation became the missing link between the recovery of post-consumer plastics and its eventual use in high-quality products. In fact, the company's name, taken straight from Webster's New World Dictionary, defines catenation as "the process of forming into links or chains."

With the help of low-interest loans and grants from the state, which generates funding through a recycling surcharge paid by businesses, the company set off to live up to its name. By 1995, recycling of HDPE and PET was going strong, but the 3-through-7 portion of the law was put on hold once lawmakers realized that the volume generated by those grades was too small to make recovery efforts worthwhile.

Tess reasons that with such a huge volume of HDPE and PET in the waste stream, going after other plastics could jeopardize already established and successful recov-

Catenation, Inc. contd.

ery systems. Besides, he adds, it makes more sense to chase the bigger piece of the pie.

"Collecting 3-through-7s may look good theoretically, but realistically, the volume opportunity for diverting waste from the landfill exists in numbers one and two," he explains. While the law is not completely off the books, it seems unlikely it will ever take hold, according to state officials. "I wasn't a fan of the 3-through-7 law," Tess says, "but we could have done some great things if it had been implemented."

Instead, Catenation jumped into PET processing—setting up a washline and pelletizing capabilities—because it became the "next logical step...and because the state made us an offer we couldn't refuse." With PET markets fizzling following the 1995 price surge for all recyclable commodities, the state was looking for a way to boost PET markets.

"We penciled a plan showing state officials we'd go the same route as we did with HDPE," Tess says. "No one was giving PET a life, but we said we think we could do

something about it."

In capitalizing on the goodwill of the state, one question begs to be asked: Can the company survive on its own? Tess says the state enabled Catenation to begin operations, but that now it is fully able to survive on its own economically. "We got help from the state to go through the learning curve, but now we've proved ourselves. And in the great scheme of things, whether a loan is made at 4% or 8% interest, it isn't going to make or break you," Tess says.

He says he feels secure in the business because he knows what to expect when markets hit the low end of the curve: "We're not like others who jumped on the band wagon at the top and then discovered problems after it was too late. We're here to survive at the bottom."

He adds, "Our product speaks for itself more than adequately. That makes us set on either end of the curve." And with the washline up and running this spring and the PET market looking hotter than it has been in awhile, Tess says, "We got dumb lucky. Our timing was just good." ■



reduced by up to about 90 % by  $\text{NH}_3$  injection. The concentrations of most of the other inorganic and organic compounds, including in particular PCDD and PCDF, did not change significantly.

## PHOSPHORUS : IN SITU TREATMENT FOR $\text{ZnCl}_2$ FORMED BY INCINERATION OF ORGANIC WASTE

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Commissariat à l'Energie Atomique (CEA), Rhone Valley Research Center  
CEA/DCC/DRRV/SCD - Marcoule - BP 171  
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### ABSTRACT

An incineration process has been developed in France for alpha-bearing radioactive organic waste. Such wastes contain polyvinyl chlorides and are rich in chlorine. They also contain zinc from neoprene and latex. Zinc chloride forms during incineration. This compound is gaseous at the combustion temperature. It is entrained with the smoke and recondenses during off-gas cooling. Depending on the incinerated waste composition, it may account for up to quasi totality of the particle matter recovered on the filters.

Zinc chloride is hygroscopic at room temperature and is highly corrosive in contact with metals when hydrated. This implies that the facility must be maintained at a temperature of  $200^\circ\text{C}$  at all times. As a secondary waste material, the  $\text{ZnCl}_2$  must be stored in dry conditions, and eventually requires a specific containment or decontamination treatment.

It is advantageous to inhibit the production of zinc chloride by favoring the formation of a more stable compound : zinc phosphate. A thermodynamic study of the stability of zinc phosphate with respect to zinc chloride showed that an excess  $\text{P}_2\text{O}_5$  over the stoichiometric fraction was sufficient to shift the equilibrium completely toward the phosphate side. This suggests that lowering the temperature also favors zinc phosphatation.

Incineration tests were carried out with phosphorus in the waste material, either by increasing the quantity of pink PVC, which contains about 1 % P, or by using a phosphorus additive. Several additives were tested : the organic liquid compound in which phosphorus is supplied to pink PVC, ammonium dihydrogenphosphate ( $\text{NH}_4\text{H}_2\text{PO}_4$  powder (which contains no additional inorganic matter) and tributylphosphate (TBP), a solvent used for reprocessing of nuclear fuel. The tests conclusively validated the thermodynamic study, and showed that the zinc phosphatation reaction was not limited by the kinetics.

The phosphorus treatment could have other applications. In the context of nuclear waste incineration phosphatation of radionuclides – which have highly volatile chlorides such as cesium chloride – could limit their entrainment in the off gas. For incineration of domestic waste as well as toxic waste, phosphatation of heavy elements would inhibit the formation of chlorides that raise disposal problems.

## COLLECTION OF HAZARDOUS GAS USING SPRAY DRYING SORBER

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Sangji University  
Department of Environmental Engineering  
Won-ju 220-702, Korea

### ABSTRACT

The purpose of this study was to find optimum operating condition and to develop chemical kinetics model of the  $\text{SO}_2$  control process for the removal of acidic gases emitted from  $\text{SO}_2$  gas (1000ppm). The control system selected in this study was spray drying sorber which could be classified as semi-dry scrubber. This study would be carried out laboratory scale research for the application to the solid waste incineration system.

To find optimum operating condition for removal of acidic gases, a laboratory spray drying sorber was designed and operated. Spray drying sorber system consisted of a drying reactor, a gas preheater, a temperature display system, lime spraying system, a bag filter, a I.D. fan, and measuring apparatus. Experiment was performed in a laboratory scale spray drying sorber which has 14m<sup>3</sup>/hr capacities, and milky lime was used. The effects of several operating parameters such as Ca/S stoichiometry, pollutant concentration, lime-slurry concentration were measured at each of 6 sampling point of the reactor. There kinds of sorbent were used in this test and These were lime slurry.

As a result of experiments, acidic gases were almost removed in the upper part of the reactor. The removal efficiency of  $\text{SO}_2$  was increased with the increase of Ca/S stoichiometry, pollutant concentration, and the decrease of flue gas temperature. The drying time of the droplet is increased as decrease the temperature. It can be found the sulfur dioxide removal efficiency could be observed over 90%.

## SESSION 8: PLASMA TECHNOLOGY

### PLASMA ARC VITRIFICATION OF INCINERATOR ASH

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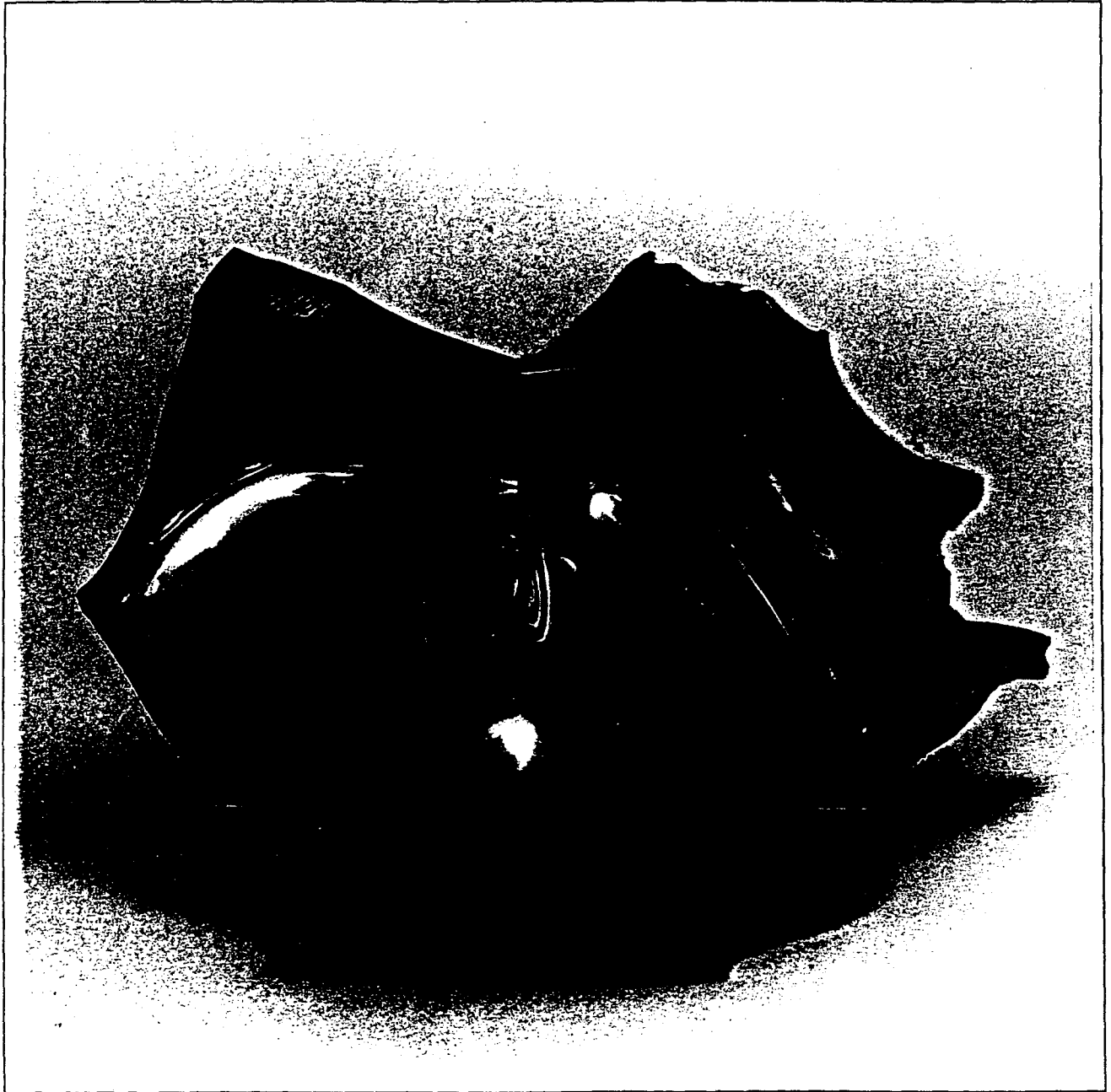
### ABSTRACT

This paper summarizes the results of an experimental test program on the plasma arc vitrification of incinerator ash. Twin electrode DC plasma torches were used to vitrify a range of grate and flyash as collected from incineration of municipal solid waste (MSW), sewage sludge waste (SSW), and hospital solid waste (HSW). Tests were conducted with both water-cooled and hollow graphite torches in a batch mode reactor operated in the electrical power input range from 35 to 75 kW. Mass and energy balances were obtained for a variety of plasma torch operating conditions and ash feedstocks. The offgas was sampled and analyzed throughout the experiment and posttest analyses were conducted on the vitreous slag. The major topics addressed in the study are:

- Characterization of ash materials from a variety of sources
- Demonstration of the plasma process and evaluation of process design alternatives
- Quantification of the effects of the process parameters on the product composition and the destruction of toxic organics



# Vitrification of Wastes



## Turning Waste into Glass

Since ancient times, glass has proved both useful and beautiful. Its combined physical and chemical properties make glass one of the most rugged materials known. Now the distinctive properties of glass are helping humankind meet one of the world's toughest environmental challenges—cleaning up hazardous wastes.

Scientists at Battelle's Pacific Northwest Laboratories are proving that vitrification—an innovative process that turns wastes into glass—is a safe, long-term solution to the problem of hazardous waste disposal. Two forms of vitrification—in situ and the ceramic melter—use high temperatures to melt radioactive and hazardous chemical wastes. Once cooled, the obsidian-like solid immobilizes wastes and is expected to retain them for a million years.

The need is urgent for vitrification—an effective, economical and environmentally sound waste management technology. Thousands of hazardous waste sites await cleanup, and the problem of waste containment and disposal continues to grow. In the United States, industry produces an estimated 33 to 44 million tons of hazardous waste per year. By the year 2000, hazardous waste generation is expected to double. Faced with the enormous challenge of waste disposal and remediation, industry and government are working cooperatively to provide more effective waste management.

### On the cover:

*Vitrification—an innovative technology that uses high temperatures to melt waste into glass—is a safe, long-term answer to the challenge of hazardous waste disposal.*

Vitrification is an effective option for handling radioactive and hazardous chemical waste. Both in situ and ceramic melter vitrification processes achieve three important goals of waste management:

- destroy or immobilize wastes
- decrease waste volume for lower disposal costs
- contain waste for extremely long periods, reducing risks to humans.

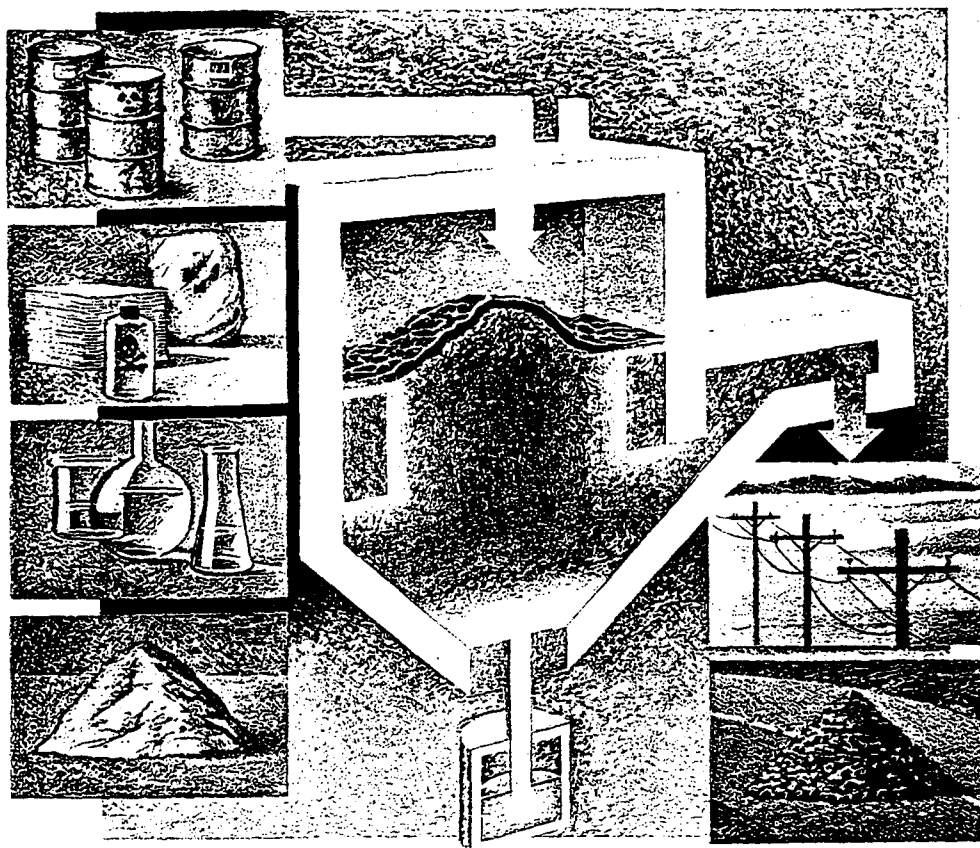
Vitrification produces a glass solid that can withstand long-term environmental exposure. The material is highly resistant to corrosion, erosion, and penetration by plants and animals.

Our scientists, under the Department of Energy's sponsorship, have developed vitrification for a wide variety of applications. The in situ process is being directly applied at disposal sites to stabilize radioactive and chemical wastes. The ceramic melter vitrifies wastes, reduces their volume, and transforms them into useful or safely disposable materials in a single step.



Computers help control temperature and power distribution during the vitrification process.

The ceramic melter can be used to treat a wide variety of wastes, including slurries and sludges, contaminated soils, combustibles, and organic materials containing heavy metals. In this one-step process of decomposition, oxidation, and vitrification, waste and chemicals are fed into the melter, where high temperatures melt and destroy the wastes. Energy can be recovered, and the resulting glass form can be used or safely disposed. The ceramic melter also includes a drain to collect valuable industrial metals and an off-gas treatment system to remove or neutralize any hazardous dusts or gases.



## Into the Melting Pot

Since the 1970s, Battelle-Northwest researchers have been developing and testing a single-step, low-cost vitrification process using a liquid-fed ceramic melter. The one-step process decomposes, oxidizes, and vitrifies the feed in a high-temperature furnace called a joule-heated, ceramic-lined melter.

Waste is combined with glass-forming chemicals and fed into the melter. Electric current is passed between electrodes to produce temperatures greater than 1500°C, melt the wastes, destroy organic material and convert hazardous heavy metals into a durable glass. While in the melter, the chemicals are thoroughly mixed and melted. The molten material is continuously drained, and its energy can be recovered. The glass product can be disposed of or formed into useful shapes.

Ceramic melter vitrification includes an off-gas treatment system that removes particulates, neutralizes acidic gases, and recycles any hazardous dusts back to the melter.

The ceramic melter technology has been rigorously tested since it was first demonstrated for waste management at Battelle-Northwest in 1975. Our ceramic melter was the world's first large-scale system capable of transforming high-level radioactive waste from spent nuclear fuel into a stable product suitable for long-term disposal. Ceramic melter vitrification technology was selected by Germany and Japan for immobilizing high-level radioactive wastes for disposal in deep geologic repositories.

## More for Your Money

The ceramic melter offers numerous benefits and wide-ranging applications for businesses and industries tackling the demanding job of waste cleanup. Waste processors using the ceramic melter technology will find it is

**versatile.** The ceramic melter can be used to treat a wide variety of waste products, including concentrated slurries or sludges and organics containing heavy metals. The process also can treat combustible wastes, trash, and pesticide-contaminated soils.

**economical.** The process transforms wastes into a chemically durable glass, which then may be delisted and used in construction as an aggregate or clean fill material. If disposal is required, the process minimizes the disposal costs by significantly reducing the waste volume. For combustibles, the glass volume can be one-tenth to one-hundredth of the waste's original volume; for ash, one-fourth.

**competitive.** Treatment costs range from \$40 to \$150 per ton, depending on the fraction of combustibles and the cost of energy.

**environmentally sound.** Ceramic melter vitrification promises to meet strict hazardous waste disposal laws. Most hazardous chemical wastes immobilized by vitrification pass the Environmental Protection Agency's toxic leach tests, making the wastes suitable for simple, safe disposal.

**accommodating.** Existing ceramic melters can process five to ten tons of waste a day, but can be adjusted to handle hundreds of tons each day. The process is well-suited for treating ash from incineration of municipal waste. Both transportable and fixed ceramic melters can be developed to satisfy specific treatment requirements.

The Battelle-developed ceramic melter technology will be used by three Department of Energy sites to vitrify high-level radioactive waste: the Savannah River site in South Carolina, which will have the world's largest vitrification plant; West Valley, New York; and the Hanford site in Washington State.



*High temperatures melt radioactive and hazardous chemical wastes to form a safe, stable solid.*

## Promising Solutions

Exploration of vitrification's unique potential is one example of Battelle's world leadership in hazardous waste research and development technology.

Ceramic melter and in situ vitrification are two of the most promising technologies to be applied to the complex cleanup of our neglected environment. Our scientists continue to advance and adapt vitrification to effectively meet needs of industry, business, and government.

We combine our technical expertise, physical facilities, and specialized equipment to develop vitrification technology to satisfy specific treatment requirements. Particular applications may require a feasibility study and an engineering analysis to tailor the design and operating specifications to the treatment requirements. Equipment is available for performing treatability tests on a variety of wastes. Tours of the field test facilities can be arranged.

## Taking the Solution to the Problem

In situ vitrification is an innovative soil-melting technology that takes the solution directly to the contaminated site.

In situ vitrification begins when an electric current is passed between electrodes placed in the ground. The power from the electric current heats the soil to 2000°C, well above the fusion temperature of most soils. The heat from the electric current melts the soil and wastes and decomposes the organic materials.

During the process, heavy metals and other inorganic materials are dissolved in the vitrified mass. As the molten material cools, it forms a glass block that chemically and physically resembles natural obsidian. Laboratory tests have determined that the product is more durable chemically than granite and marble, making it an ideal material to stand the test of time.

To reduce heat losses and contain any volatile gases that may be emitted during vitrification, a portable insulated hood covers the melt. Any toxic and radioactive material is removed before gas is released.

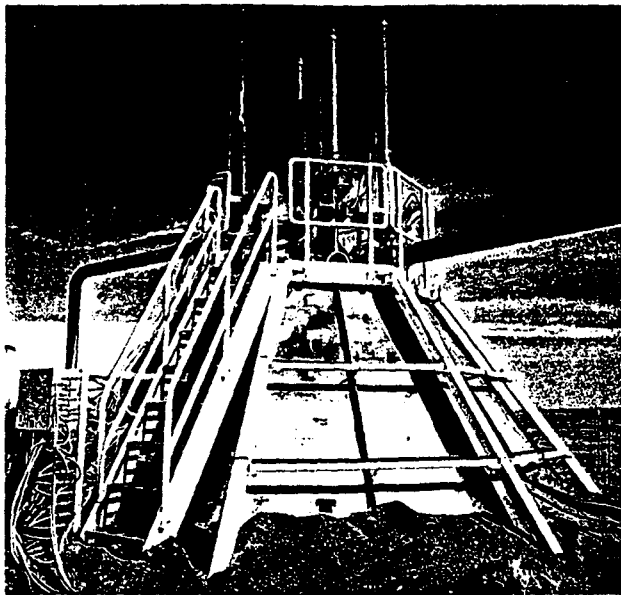
### Unique Process for a Common Problem

In situ vitrification offers numerous advantages over other technologies. This unique thermal treatment process is

**safe.** Because the waste is not exhumed, pretreated or moved, in situ vitrification does not expose operators, transport workers, or residents to contaminants.

**cost-effective.** Typical treatment costs are significantly less than for incineration or destruction/immobilization options.

**a permanent solution.** In situ vitrification destroys or removes organics and immobilizes heavy metals in a stable form for about a million years.



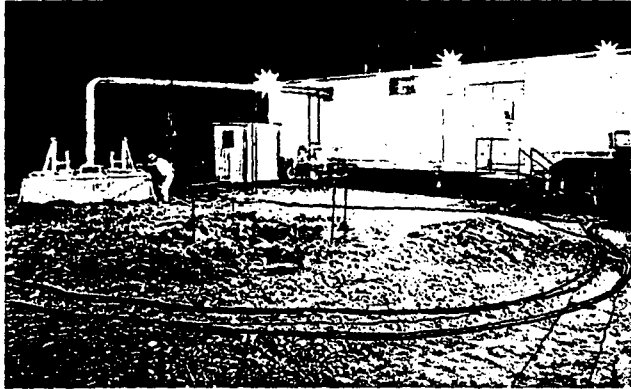
*A portable hood placed over the vitrification site reduces heat loss and contains any volatile gases from the process. In situ vitrification treats only the problem, producing virtually no secondary wastes.*

**versatile.** The process offers simultaneous processing of widely varying mixtures of wastes, including organics, inorganics, soils, sludges, and refuse. Field systems can be developed to handle simple or complex materials, including large waste volumes.

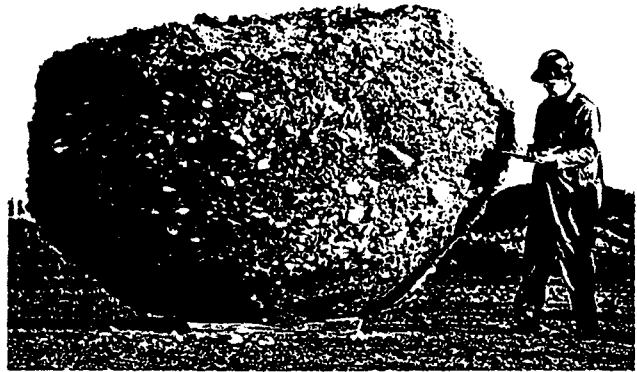
**mobile.** In situ vitrification is operated using three trailers. Power can be supplied by local utilities or by diesel-powered generators.

**efficient.** In situ vitrification treats only the problem, producing comparatively little secondary waste such as contaminated clothing, tools, and transport equipment.

There are other on-site thermal processing technologies in use, but none have the capabilities or advantages of in situ vitrification. Most technologies require excavation and pretreatment prior to processing. Processes such as incineration may partially remove organics but do not immobilize the remaining contaminated soil. Air pollution also is a concern with incineration. Other in-place technologies are not capable of the high-temperature treatment of in situ vitrification, and they do not produce a material acceptable for long-term environmental exposure.



*In situ vitrification takes mobile units directly to the site and avoids the need to exhume, pretreat, and move the contaminated soil.*



*Vitrified rock, resembling natural obsidian, can withstand long-term exposure.*

## Diverse Applications Evolve

In situ vitrification can solve a wide range of waste management problems for government and industry. The technology is being employed at contaminated soil sites throughout the United States. Further development of in situ vitrification technology is now under way for its application to

- soil containing very high concentrations of contaminants
- buried combustible and metallic wastes
- underground waste storage tanks
- producing impermeable cut-off walls and a floor to prevent the movement of groundwater into or out of contaminated areas.

Our researchers are using computer modeling to engineer greater melt depths for in situ vitrification and to optimize ceramic melter design. Modeling shows, for instance, the importance of convection patterns in the ceramic melter for maintaining homogeneity. It also reveals how important it is to concentrate electrode power at the bottom of the in situ vitrification melt.

## About Battelle

Battelle-Northwest is a division of Battelle Memorial Institute, an independent organization devoted to scientific research and development. In addition to its corporate headquarters in Columbus, Ohio, Battelle has established major research centers in Richland, Washington; Geneva, Switzerland; and Frankfurt, Germany. Battelle has a staff of 8,200 engineers, scientists, and specialists, and an annual research volume exceeding \$610 million.

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# ENVIRONMENTAL PRODUCT PROFILES

## Vortec Combustion and Melting System

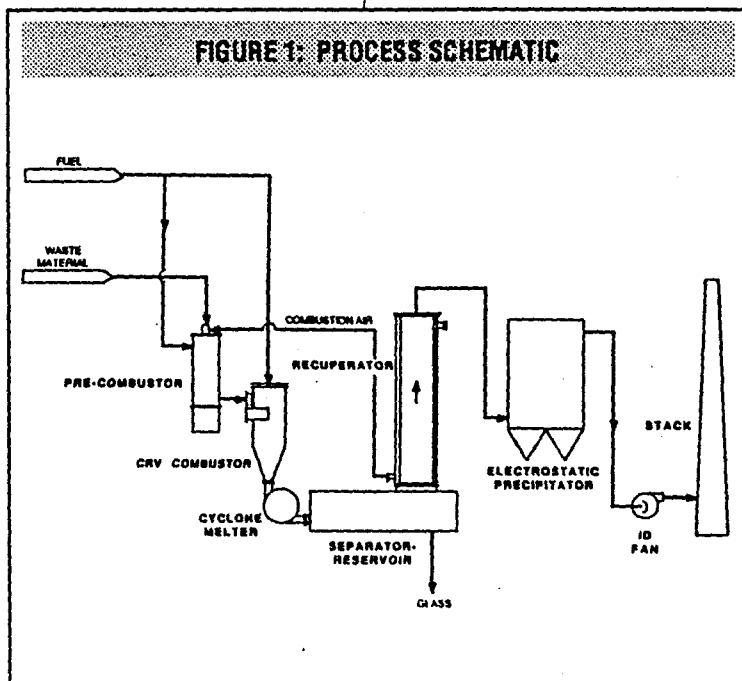
### Process Description

- ▲ Oxidation
- ▲ Vitrification

The Vortec Combustion and Melting System (CMS) treats hazardous wastes and contaminated residuals by (1) oxidizing organic contaminants and (2) immobilizing inorganic contaminants within a glassy, vitrified matrix. The system consists of a patented heating device and specially designed components that provide process conditions required for vaporization of water and volatile organic contaminants (VOCs), combustion of VOCs, and formation and separation of the glass product. The CMS technology, which also has applications in glass manufacturing, is unique in that it can be heated by a variety of fuels, including pulverized coal, coal slurries, natural gas, fuel oil, and petrocake. Other reported advantages include the ability to treat organic and inorganic con-

taminants using a single system, formation of a non-leaching product, and the ability to oper-

ate as a batch or continuous process. A schematic of the process is provided in Figure 1.



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*Environmental Technology  
and Product Profiles*, a  
NETAC publication featuring  
innovative and emerging  
environmental technologies.

### Process Application

- ▲ Solid Wastes
- ▲ Soil
- ▲ Sediment
- ▲ Sludge
- ▲ Organics
- ▲ Inorganics
- ▲ Metals
- ▲ Radionuclides
- ▲ Permanent
- ▲ Transportable

Major environmental applications for the Vortec system include vitrification and recycling of a variety of waste materials. Vitrification applications include treatment of soils, sediments, sludges, and mill tailings containing organic, metallic, or radioactive contaminants. Recy-

cling applications include treatment of waste glass and scrap fiberglass materials. Table 1 lists specific wastes amenable to treatment. Most organic, metallic, and radioactive contaminants can be handled by the system. Vortec reports that the vitrified products are non-leaching and can be

disposed as a non-hazardous waste, recycled as raw materials, or processed into saleable by-products. Vortec plans to use the technology within fixed, permanent treatment facilities as well as transportable units designed for on-site remedial applications.

**TABLE 1: WASTES AMENABLE TO TREATMENT**

Municipal incinerator flyash  
Utility flyash  
Waste glass  
Waste insulation fiberglass  
Aluminum processing flyash and dust  
Asbestos  
Foundry sand

Low-level radioactive waste  
Hospital and medical waste  
Contaminated soils and sludges  
Electric arc furnace dust  
Spent pot liners  
Filter cakes  
Shredder fluff

# ENVIRONMENTAL PRODUCT PROFILES

## Vortec Combustion and Melting System

### Process Operation

- ▲ Continuous
- ▲ Batch
- ▲ Dry or Slurry Feed
- ▲ Precombustor
- ▲ CRV Combustor
- ▲ Cyclone Melter
- ▲ Separator
- ▲ Recuperator
- ▲ Air Pollution Control System

The process can be operated on a continuous or batch basis, and waste can be fed in dry or slurry form. The CMS consists of (1) a precombustor, (2) a counter rotating vortex (CRV) combustor, and (3) a cyclone melter. Wastes are first fed into the precombustor where vaporization of water and partial oxidation of organic contaminants occurs under proprietary conditions. The waste is then combined with fuel and glass-making ingredients in an in-flight suspension preheater and fed to the CRV combustor where temperatures of up to 3,000°F complete the combustion of volatiles and achieve melting of the inorganic materials. The resulting molten mixture is fed to the cyclone melter where gas-induced centrifugal forces result in formation of a glass layer on the melter walls. The liquid glass products and combustion gases

exit the cyclone melter through a common chamber and enter a separator. Gases are routed to a recuperator (to recycle heat to the precombustor), after which they are delivered to a conventional air pollution control system for

particulate removal or acid gas clean-up. The molten glass is removed from the separator using a slag tap and then quenched with water and stored for subsequent recycle or disposal. Pilot plant operating parameters are summarized in Table 2.

**TABLE 2: PILOT PLANT OPERATING PARAMETERS**

Throughput	15 to 20 ton/day
Fuel options	Pulverized coal, natural gas, oil, petrocake, waste liquid or solid fuels
Operating temperatures	
Precombustor	Proprietary
CRV combustor	1,700 to 2,500°F
Cyclone melter	2,000 to 3,000°F
Required utilities	
Cooling water	30 gpm
Electricity	30 kW

### Vendor Information

- ▲ Bench
- ▲ Pilot
- ▲ Commercial

Founded in 1984, Vortec Corporation provides engineering services, process equipment, and R&D for glass manufacturing and other high-temperature processes. Work with the CMS began in 1982 and major funding support from the Department of Energy (DOE) was provided in 1987. In 1988, the company completed construction of a 20 ton/day pilot unit that it operates at the University of Pittsburgh Applied Research Center (Harmarville, Pennsylvania). To date, 32 tests with more than

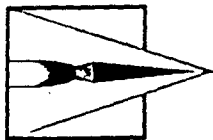
200,000 pounds of material have been conducted using this unit. In May 1991, the technology was accepted by the U.S. EPA SITE Emerging Technology program. The demonstration will include treatment of laboratory-prepared contaminated soils at Vortec's pilot plant facilities and will be initiated in early 1992. In September 1991, Vortec announced receipt of a \$4 million DOE contract for additional development of its CMS process. Work will focus on use of the technology

for recycling of boiler and incinerator flyashes into construction material feedstocks and mineral fiber products, using pulverized coal as the primary fuel source. Table 3 lists key developmental milestones for the Vortec technology. Vortec is actively pursuing the licensing of its technologies and joint ventures for recycling applications. The CMS will be used as the key process element in a glass recycling facility expected to be constructed in 1992.

**TABLE 3: KEY DEVELOPMENTAL MILESTONES**

Year	Description
1982	Process development initiated
1988	Process feasibility demonstrated at 10 to 20 ton/day
1990	Proof-of-concept testing completed at 10 to 20 ton/day
1991	Commercial system designs initiated for process units with 2 to 200 ton/day capacities
1992	Commercial units provided for selected waste processing applications





# Plasma Technology

# Aerotherm

## General Capabilities

Aerotherm Corporation, a subsidiary of DynCorp in Mountain View, California, has more than 30 years of experience in electric arc plasma technology, including analysis, testing, and design. Organizations such as NASA, USAF, Sandia Laboratories, and many aerospace companies have tested thermal protection materials and systems for solid rocket nozzles, ramjet combustors, reentry vehicles, and missile radomes in the Aerotherm Plasma Lab (APL). In addition, Aerotherm has a staff of engineers and scientists experienced with modeling the effects of interactions of plasmas with materials, specifically in the areas of aerothermochemistry, fluid dynamics, heat transfer, structural dynamics, instrumentation, and process design.

## Aerospace Test Facilities

Aerotherm has designed and built plasma systems with input power from 80 kW to 24 MW, including a recent 450-kW plasma heater for an aerospace test facility at the National Aerospace Laboratory, Tokyo, Japan. We are currently working on the design of a 70-MW aerospace test facility for the Centro Italiano Ricerche Aerospaziali (CIRA) organization in Italy, which is sponsored by the European Space Agency.

## Materials Production

Aerotherm has also conducted plasma torch research and development for commercial applications, and some of this work has also included design and fabrication of turnkey plasma torch systems. Our work for SKF Steel in Hofers, Sweden, is a good example. SKF approached Aerotherm to help them develop plasma systems for various processes, including a proprietary steel smelting technology. We carried out extensive testing in our plasma laboratory to develop torch configurations providing optimum performance in terms of parameters such as gas enthalpy, torch efficiency, and electrode lifetime. We also delivered a 1-MW plasma torch to SKF to enable them to conduct further testing and development in their facility.

## Environmental Remediation

Aerotherm is currently working with the DOE Western Environmental Technology Office (WETO) to develop plasma technology for the vitrification of low-level radioactive mixed waste. Aerotherm has developed an alternative plasma torch for WETO's Small Scale Plasma Furnace Program. This 160-kW torch is unique because it provides long electrode life and high enthalpy. Aerotherm is also developing a Twin Torch™ reactor system for WETO. It is tailored to the research objectives of WETO and includes feed and receiver subsystems.

## Advanced Processes

Aerotherm maintains a strategic alliance with Tetronics Research and Development of Faringdon, Great Britain, which has developed the patented Twin-Torch™ plasma technology. Tetronics has 25 years of experience with a wide array of industrial plasma processes for applications from pilot to full-scale operations. Combining Aerotherm's scientific expertise with Tetronics's industrial experience offers advanced capabilities for the design, test, and operation of plasma process facilities.



*A Twin-Torch™ plasma heater, which controls the temperature of molten steel in a tundish, exhibits Aerotherm's ability to provide torches for commercial processes.*

Please contact Dr. Calvin Wolf with your inquiries and requests

## **Aerotherm Corporation**

**A Subsidiary of DynCorp**

580 Clyde Avenue, Mountain View, California 94043

Phone: (415) 254-2567 Fax: (415) 964-8349 Internet: [wolf@aerovax.com](mailto:wolf@aerovax.com)

# PROJECT OBJECTIVE To demonstrate the vitrification

## THE INCINERATOR ASH PROBLEM

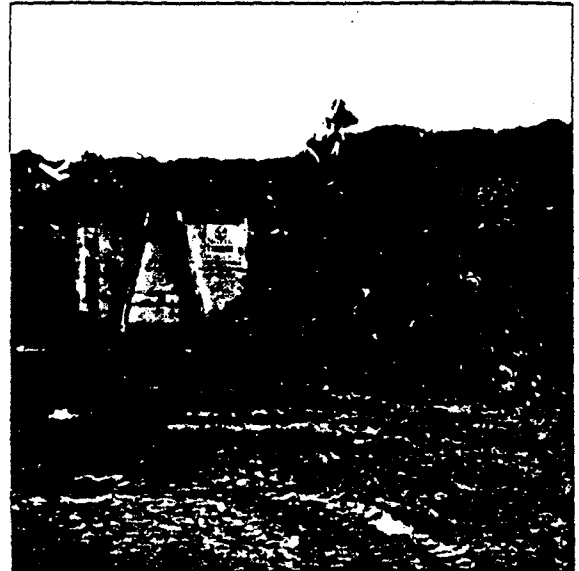
In the developed world, a large and increasing proportion of combustible solid waste arisings are incinerated. Over 100 million tonnes of municipal solid waste (MSW) and 4 million tonnes of sewage sludge waste (SSW) are burned annually world-wide. The ashes produced from incineration (15-20% by mass of the feed material) are of low bulk density and contain leachable toxic heavy metal species and persistent toxic organics. At present, the majority of incinerator ashes are disposed of to landfill.

However, in many countries this situation is not sustainable due to the increasing scarcity of suitable landfill sites and the introduction of more stringent environmental laws. Many ashes are susceptible to leaching of heavy metals and other components. Consequently there will be a requirement for alternative methods of dealing with incinerator ashes that are able to reduce the volume of the product and decrease its possible environmental impact.

## THE PROJECT

In 1993, Tetronics, in association with Geochem, began a two-year research and development programme to investigate the development of the Tetronics DC plasma process for application to the vitrification of waste ashes generated from incineration of two major waste streams: MSW and SSW. The objective of the project was to determine whether DC plasma treatment could be used to produce a high density, environmentally stable product from incinerator ashes. The following tasks were involved in the project:

- The sourcing and characterisation of ash materials
- Demonstration of plasma arc vitrification of waste ashes
- Investigation of process conditions to vitrify the waste and treat the toxic organics
- Characterisation of the slag and the leachability of its components
- Quantification of the environmental benefits from the process

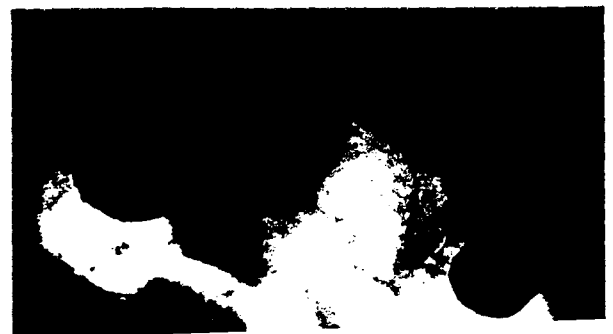


*Starting materials*

## PLASMA VITRIFICATION

Plasma arc electrode systems are simple and robust to operate and are used for large scale operation. Plasma water cooled torches are applicable when it is necessary to operate under strongly oxidising conditions. The twin DC plasma system was designed to operate with a high degree of flexibility allowing the testing of either water cooled torches or hollow graphite electrodes.

A range of MSW and SSW ashes collected from different incinerators were tested. Close control and monitoring of the system was undertaken which ensured that efficient vitrification of the feed ash material was achieved for all of the incinerator ashes tested.



# of incinerator ashes and the non-leachability of the slag

## ENVIRONMENTAL BENEFITS

An assessment of the environmental benefits of the vitrification process demonstrated several positive features:

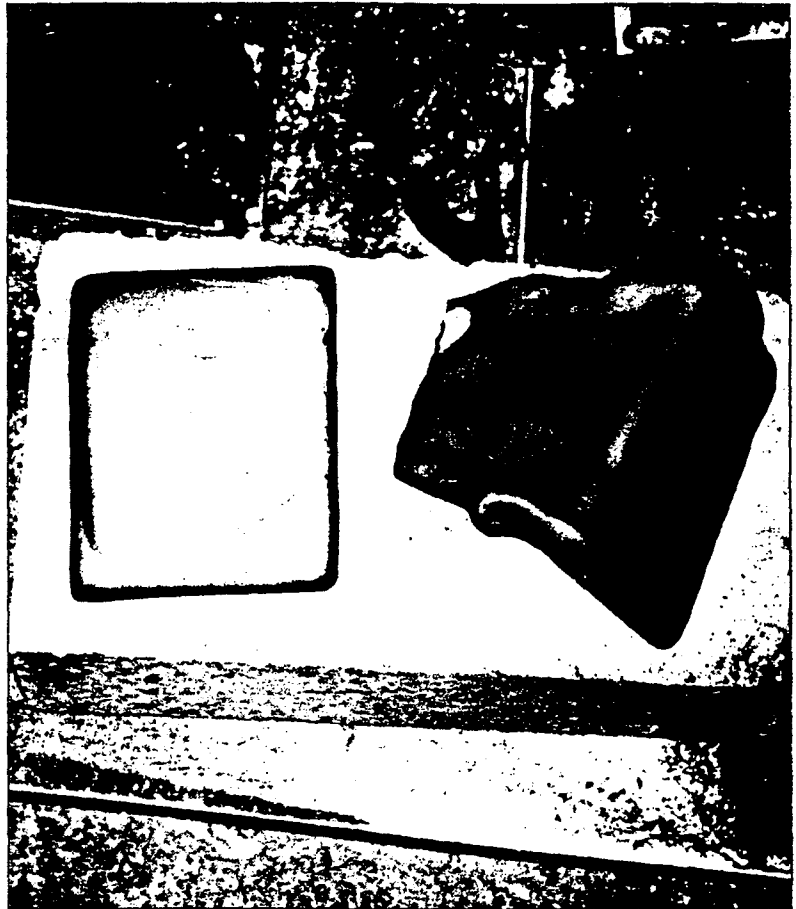
- The leachability of toxic metal species was reduced to meet proposed EC and existing US leaching test criteria for non-hazardous waste
- The volume of the product was substantially reduced
- The levels of persistent organics were reduced to negligible levels in the product streams
- Only low amounts of off-gases were generated during the process

## FUTURE DEVELOPMENTS

In order to increase the economic benefits from the process, it has been proposed that the melt composition and cooling regimes should be closely controlled to produce a high quality semi-crystalline glass that could be used as a substitute for marble or granite building materials.

## TOWARDS COMMERCIALISATION

Based on the success of the plasma technology, six pilot plants treating incinerator ashes have been installed in Japan and orders for two commercial scale plants have been confirmed. Tetronics plasma systems have been used in the commercial treatment of a wide range of waste material arisings. This project demonstrated that the technology can now be used to produce an environmentally inert product from incinerator ashes, thereby opening up a new avenue for application of the technology.



△ Vitrified product

## POTENTIAL USER INDUSTRIES

- Ash producers - MSW, SSW, HSW, power generators
- Ceramics - vitrification of refractory fibres
- Glass - vitrification of fibres
- Nuclear - vitrification of waste
- Asbestos - vitrification of fibres
- Tile manufacturers - synthetic marble/granite, coloured tiles

## DTI SUPPORT

The DTI supported this collaborative research project under the Environmental Technology Innovation Scheme (ETIS) contributing around £ 260 000 to the total project cost of £ 520 000.

## ETIS

The Environmental Technology Innovation Scheme (ETIS) was jointly managed by the Department of Trade and Industry (DTI) and the Department of the Environment (DoE). The scheme, which ran from October 1990 until September 1993, provided grant assistance for pre-competitive industrial research in the environmental field.

Its aim was to encourage technical innovation to improve environmental standards and help users and suppliers of environmental technology become more competitive.

ETIS has supported research projects in the following areas: recycling, cleaner technologies, environmental monitoring, industrial waste treatment/disposal and effluent treatment/disposal.

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The logo for the Department of Trade and Industry (DTI), featuring the lowercase letters 'dti' in a bold, stylized font.

**Department of Trade and Industry**

# Pacific Northwest National Laboratory

*Operated by Battelle, for the U.S. Department of Energy*

## Emerging Technology Profile: *Glow Discharge Plasma*

Glow Discharge Plasma (GDP) is a method developed by the Department of Energy at the Pacific Northwest National Laboratory to create a non-thermal plasma directly on the surface of a liquid. When GDP is applied to water, the plasma generates highly reactive species which react with contaminants in the water. The technology can be applied to hazardous, or toxic organic contaminants in water. It is especially effective for treating materials which are considered recalcitrant to other methods of destruction.

The potential advantages of GDP are:

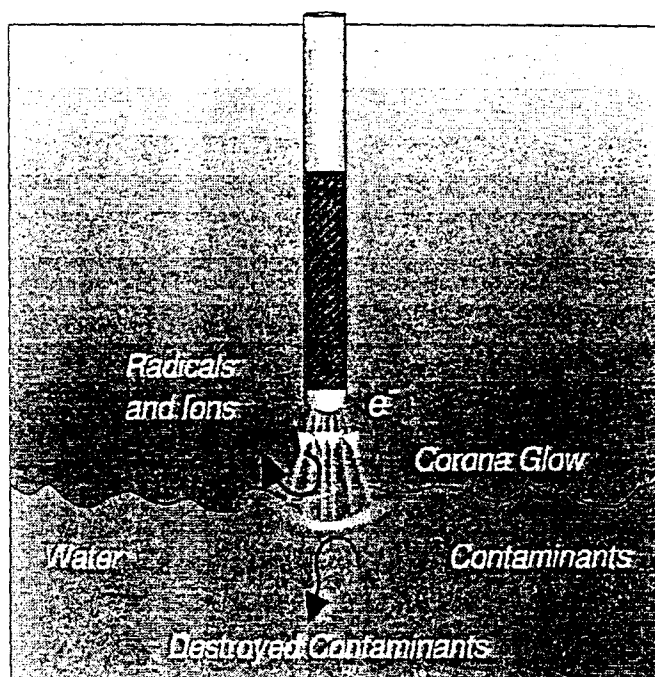
- Highly reactive species are created directly from the water and in the vapor space.
- No reactive chemicals like peroxide or ozone are necessary.
- Can treat contaminants not effectively treated by advanced oxidation technologies.

**How it Works:** Glow Discharge Plasma uses an electric field to accelerate electrons sufficiently to create ions and radicals in the gas contacting the liquid. As some of the electrons fall from higher energy levels to lower energy levels, they emit photons creating a glowing plasma between the electrode and the water. That's where the name "glow" comes from. The work, however, comes from the active species created by the energetic electrons.

GDP can generate very energetic species like hydroxyl radical,  $\bullet\text{OH}$ , which are strong oxidizers. However, other mechanisms besides oxidation give GDP the ability to destroy a wider range of contaminants than conventional advanced oxidation. GDP has been shown to destroy carbon tetrachloride and perchloro ethylene; which are not considered susceptible to oxidation.

**Costs:** Projected operating costs for GDP have been compared to existing advanced oxidation technologies. Since no added chemicals are needed, the expected operating costs are essentially the cost of the electricity.

GDP was used to treat water contaminated with 40ppm pentachlorophenol (PCP). Power costs to achieve 90+% destruction were \$1-\$2 per 1000 gals. By comparison, costs published for UV/H<sub>2</sub>O<sub>2</sub> advanced oxidation to treat PCP contaminated water (10ppm)



were between \$1.25 and \$3 per 1000 gals.

**Status:** GDP is an emerging technology. Its effectiveness, kinetics, and power requirements have been demonstrated on the laboratory scale. Scale-up parameters to build a demonstration pilot plant are being developed.

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